NAVAL POSTGRADUATE SCHOOL
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THESIS

DEVELOPMENT OF GRAPHICAL POLE-ZERO, ROOT-LOCUS, BODE, NYQUIST, AND NICHOLS RESPONSES USING THE OPTSYSX PROGRAM

by

Michael Henry Laptas

September 1984

Thesis Advisor: Daniel J. Collins

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This thesis discusses the modification of and additions to an existing Optimal Systems Control FORTRAN Program (OPTSYS) originally obtained from Professor Arthur E. Bryson of Stanford University. This program has been subsequently redesigned to run interactively on the IBM 3033 VM/CMS by Lieutenant Commander John G. Hoden, and additions by Commander Harry A. Diel provide the user with a highly accurate graphic time response to a system designed using the OPTSYSX program.

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This series of programs permits users to rapidly carry out simulation, analysis, and design of Optimal Systems Control problems in a totally interactive mode.

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Development of Graphical Pole-Zero, Root-Locus, Bode, Nyquist, and Nichols Responses using the OPTSYSX Program

by

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ABSTRACT

This thesis discusses the modification of and additions to an existing Optimal Systems Control FORTRAN Program (OPTSYS) originally obtained from Professor Arthur E. Bryson of Stanford University. This program has been subsequently redesigned to run interactively on the IBM 3033 VM/CMS by Lieutenant Commander John G. Hoden, and additiors by Commander Harry A. Diel provide the user with a highly accurate graphic time response to a system designed using the OPTSYSX program.

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SYMBOLS

A = State (Ns,Ns) or Output (No,No) Weighting Matrix
B = Control (Nc,Nc) Weighting Matrix
C = Control Gain Matrix (Nc,Ns)
D = Control (No,Nc) or Noise (No,Ng) Feedforward Matrix
F = Open-Loop Dynamics Matrix (Ns,Ns)
G = Control Distribution Matrix (Ns,Nc)
GAM = State Disturbance Distribution Matrix (Ns,Ng)
H = Measurement Scaling Matrix (No,Ns)
K = Estimator Gain Matrix (Ns,Nob)
Nc = Number of Ccntrols
Ng = Number of Process Noise Sources
Ns = Number of States
No = Number of Observations or Measurements
Q = White Process Noise Covariance Matrix (Ng,Ng)
R = White Meas. Noise Covariance Matrix (No,No)
S = Steady-State Covariance Matrix of Control (Nc,Nc)
u = Control Vector (Nc,1)
v = White Measurement Noise Vector (No,1), with Zero Mean and Covariance Matrix R
w = White Process Noise Vector (Ng,1), with Zero Mean and Covariance Matrix Q
w0 = Constant Disturbance Vector (Ng,1)
x = State Vector (Ns,1)
xdot = Derivative cf State Vector (Ns,1)
xe = Estimate of State Vector (Ns,1)
xedot = Derivative cf Estimate of State Vector (Ns,1)
y = Output Vectcr (No,1)
z = Measurement Vector (No,1)

I. INTRODUCTION

The purpose of this thesis is to describe the modification and additions tc the existing FORTRAN program (OPTSYS) which is used in the study and application of Optimal Systems Ccntrol theory.

The OPtimal SYstems control program was originally developed by Hall [Ref. 1] to support his research in rotary-wing aircraft control systems. Later program modifications were made by Walker [Ref. 2] and Liu [Ref. 3] of Stanford University, and are designated OPTSYS 4 and OPTSYS 5 respectively. OPTSYS modifications made by Hoden [Ref. 4] were primarily devoted to creating a user-friendly interactive version (OPTSYSX) of the OPTSYS 4 program. The latest modifications by Diel [Ref. 5] allowed the user to save matrices for subsequent runs of the OPTSYSX program, and formed data file sets for the time response program OPTCALC.

The intent of this thesis work was to develop an interactive program to plot the Pole-Zero map, Root-Locus, Bode, Nyquist, and Nichols responses to the open loop, closed loop noise, and compensator transfer functions of a State Variable Control System which has been developed using OPTSYS Program. Mincr modifications to the OPTSYSX Program were necessary to ccnstruct a data file sets for plotting the Pole-Zero Map, and in calculations for the Root-Locus, Bode, Nyquist, and Nichols plots.

It is assumed that the user is familiar with the basic concepts of Control Theory and Optimal Systems Design. The symbol/naming conventions of Bryson [Ref. 6]. are used in the discussion of program operations and descriptions of problems using the OPTSYS System.

An overview of the OPTSYSX Program capabilities and of modifications to the existing programs is presented first. This is followed by a description of the program (OPTGRAPH), which was developed tc plot the Pole-Zero Map and to perform calculations for the Root-Locus, Bode, Nyquist, and Nichols plots.

This work concludes with examples of various types of problems demonstrated in the interactive mode, including a copy of each terminal session with the final results. Complete program listings for the OPTSYS EXEC program, CPTSYSX program, and CPTGRAPH program are included in appendices A,B, and C respectively.

II. THE OPTSYSX COMPUTER PROGRAM

A. BACKGROUND

OPTSYSX is a double-precision, interactive FORTRAN program employing modern control theory analysis techniques. Its capabilities include the calculation of the open-loop eigensystem, and the stationary closed loop system; the synthesis of regulators and filters; along with power spectral density, and modal distribution computations. The modifications introduced to the OPTSYSX program by this thesis work do not affect the program's original capabilities.

B. OVERVIEW

OPTSYSX is an extremely large and complex program with over 3000 lines of code. To use the program in its small version (dimensioned for a 32 X 32 "F", "G", and "H" matrices), the user must extend his Virtual Machine (VM) memory capacity beyond the default VM memory capacity of 720 kilobytes to 1024 kilobytes.

Any significant increase in the OPTSYSX program size, with the the resulting requirement for additional memory capacity, would cause user difficulties. For this reason the task of obtaining the Pole-Zero maps, Root-Locus, and Bode, Nyquist, Nichols plots for the open loop, noise and compensator transfer functions was relegated to a separate program (OPTGRAPH). Three data files (OPTGROL DATA, OPTGRNO DATA, and OPTGRCM DATA), containing the open loop, noise, and compensator transfer functions, are formed by the OPTSYS program to be transfered to the OPTGRAPH program. The OPTSYS EXEC program provides an interface between the

OPTSYSX program, the time response programs (OPTCALC and OPTPLCT), and the OPTGRAPH program.

C. OPTSYSX MODIFICATIONS

OPTSYSX program modifications consist of the addition of write statements, three flags, and a short routine to interpret user inputs.

Write statements,to input data to the OPTGROL, CPTGRNO, and CPTGRCM DATA files were added to the main program, subroutine INNER, subroutine ZEROS, and subroutine POLES. System information ccnsisting of number of states (Ns), number of controls (Nc), number of measurements (No), number of process noise scurces (Ng), type transfer function (ITFX), Markov Parameter (IE), and two flags to be used by the OPTSYS EXEC and the OPTGRAPH programs is inputed from the main program. The write statements added to the subroutine INNER, and subroutine POLES input the poles for the open locp and noise transfer functions, and compensator transfer function respectively. The zeros, the numerator order, the gain, and the input and output numbers for all three transfer functions are obtained from the subroutine ZEROS.

The first of the two flags, input with the system infcrmation from the main program to the three data files, serves as a marker for the CPTSYS EXEC to locate the correct data line for reading system inputs. The second flag, which is set by the routine tc interpret user inputs, serves as a signal for the OPTSYS EXEC to either load the OPTGRAPH program if any one of the three transfer functions was calculated by the OPTSYSX program, and abort loading the OPTGRAPH program if none of the three transfer functions were calculated. The third flag (ITFX) is an existing OPTSYSX program flag. The flag (ITFX) is passed from the

subroutine TF to the subroutine ZEROS to identify the calculation of either an open loop, noise, or compensator transfer function zeros.

The short routine added to the main program of OPTSYSX reads the flags ITF1, ITF2, ITF3, and IRET. The flag sent to the OPTGROL, OPTGRNO, or OPTGRCM DATA files is set to allow loading of transfer function data file to the OPTGRAPH program if the user selects either of the transfer function options number two (calculate poles, residues, and zeros - ITF1 = 1, ITF2 = 1, or ITF3 = 1) number three (calculate poles, and zeros - ITF1 = 2, ITF2 =2, or, ITF3 = 2) when calculating the open loop, noise, or compensator transfer functions. The selection of any other transfer function option will not calculate the transfer function zeros. The flag IRET is read to determine if the user desires to rerun a problem without exiting the OPTSYSX program. Should the user elect to rerun a problem without exiting OPTSYSX (IRET = 1), the three data files are set back to the beginning (REWIND) to accept the new problem system data.

D. OPTSYS EXEC MODIFICATIONS

The OPTSYS EXEC was written by Diel [Ref. 5] to interface between the OPTSYSX program and the time response programs OPTCALC and CPTPLOT. The modifications to the exec program were to add the option to select running the OPTGRAPH program to the exec menues and a short section to interface the OPTGRAPH program with the OPTSYSX program.

The added section to interface between the OPTSYSX and OPTGRAPH programs defined loader size (LDRTBLE), file definitions (FILEDEF), and text libraries (TXTLIB) for the CPTGRAPH program. The first line of the three data files is read to ensure that there has been at least one of the three transfer functions calculated by the OPTSYSX program prior to loading OPTGRAPH program.

The OPTSYS EXEC routine is also used to send plots to the VERSATEC plotter from the OPTPLOT program and the OPTGRAPH program.

III. THE OPGRAPH PROGRAM

A. PROGRAM OVERVIEW

OPTGRAPH is an interactive FORTRAN program which uses the transfer function poles and zeros calculated by OPTSYSX to calculate, tabulate, and plot the Pole-Zero Map, Bode, Nyquist, Nichols, and Root-Locus responses for either the open loop, closed loop noise, or compensator transfer functions.

1. Program Language

CPTGRAPH is programmed in FORTRAN following the conventions of the IBM System /360/370/ FORTRAN IV language. CPTGRAPH has been ccmpiled and run under both FORTRAN IV (G1) and FORTRAN H (extended) compilers on the IBM 3033.

2. Graphics Package

This program uses the Display Integrated Software System and Plotting System Software (DISSPLA) developed and distributed by the Integrated Software Systems Corporation (ISSCC) of San Diego, California. The DISSPLA package is a library of FORTRAN subroutines using FORTRAN IV conventions.

3. Library Subroutines

CPTGRAPH uses the International Mathematical and Statistical Library (IMSL) subroutine ZRPOLY to calculate the roots of a polynomial equation. ZRPOLY is a double precision FORTRAN subroutine to which is input a polynomial with real coefficients (double precision) in terms of decreasing powers of the polynomial. The subroutine finds the roots of the polynomial and returns a double precision

complex array containing the roots. ZRPOLY is capable of accepting polynomials greater than 0 order and less than 101 order.

4. Program Composition

CPTGRAPH has one main program and 24 subroutines. The main program and its subroutines may be divided into four basic categories:

1) File Data Input
2) Interactive Data Input
3) Plot Setup and Sequencing
4) Calculation

A brief and general description of the program and its subroutines will follow in subsequent sections.

B. GENERAL PROGRAM OPERATION

OPTGRAPH was written to satisfy two specific objectives. The first is to create a program to be used as a instructional tool for students taking controls related courses, and the second is as method to assist in the analysis of actual large order control system problems.

To accomplish these objectives the emphasis while writing this program was to make the program as user oriented as possible by attempting to eliminate ambiguities and providing features which would protect the user from inadvertent wrong entries. An effort was also made to minimize the Virtual Machine (VM) memory required to execute the program to facilitate the analysis of a large order system.

1. User Protection Features

Three basic methods were used to protect the user from an abnormal program termination in the case of an inadvertent wrong entry. The first was to construct the

subroutines to display a summery of the user inputs and allowing changes prior to leaving the subroutine. For the case where the user input is expected to fall within a given range, the input is examined and the user is either allowed to continue for an input within the range or issued an error or warning and reasked the question for an input outside the range. The final method is used by the three subroutines which read the user input from the screen. The subroutines RDINT, RDREAL,and RLCHAR expect an integer input, real number input, and a logical "yes" or "no" respectively. In the event that a "null" line is inadvertently entered, the user is issued a warning and allowed another opportunity to enter the the correct input before abnormally terminating the program. The entry of two "null" lines also offers the user the option to to exit the OPTGRAPH program at other than normal program exit points. The subroutine RDCHAR also examines the input and issues a warning if the input is not either "yes" or "no".

2. Large Order System

The large order control problem being considered for analysis by the OPTSYSX and the OPTGRAPH programs is the X-29A aircraft longitudinal axis backup mode system. This system has a (98 X 98) "F" matrix , a (2 X 98) "H" matrix, and a (98 X 1) "G" matrix.

To accommodate this large order system the OPTGRAPH program was dimensioned to accept a system with a maximum of 99 states (Ns), 12 controls (Nc), 12 process noise sources (Ng), and 12 measurements (No). The Virtual Machine (VM) memory requirements for the program were minimized by the reuse of memory locations allocated for storage of calculated data after that data has been either tabulated or plotted. This method of memory reuse has allowed the OPTGRAPH program to be dimensioned to accommodate a large

order system and still operate with less than the 1024 KILOBYTES VM memory required to run OPTSYSX in its small version.

C. SYSTEM/MODEL DESCRIPTION

The system equations used by the OPTSYSX program for the calculation of the transfer functions are of the state variable form. The system equations are:

system model

$$xdot = [F]*x + [G]*u + [GAM]*w \tag{3.1}$$

measurement equation

$$z = [H]*x + [D]*u + v \tag{3.2}$$

estimator equation

$$xedot = [F]*xe + [G]*u + [K]*(z - [H]*xe) \tag{3.3}$$

open loop transfer function

$$[H]*|s[I] - [F]|^{-1}*[G] \tag{3.4}$$

closed lcop noise transfer function

$$[H]*|s[I] - [F]|^{-1}*[Gam] \tag{3.5}$$

compensator transfer function from measurement to input

$$[C]*(|s[I]-[F]+[G]*[C]+[K]*[H]|^{-1})*[K] \tag{3.6}$$

where

u = Control vector (Ns X 1)

w = White process noise vector (Ng X 1)
x = State vector (Ns X 1)
xdot = Derivative of the state vector (NS X 1)
y = Output vector (No X 1)
z = measurement vector (No X 1)

[C] = control gain matrix (Nc,Ns)
[D] = control feed-forward distribution matrix (Nc,Nc) of the control vector (u)
[F] = open-loop dynamics matrix (Ns,Ns) (System matrix or Plant matrix)
[G] = control distribution matrix (Ns,Nc)
[GAM] = state disturbance distribution matrix (Ns,Ng)
[H] = measurement distribution matrix (No,Ns)
[I] = identity matrix (Ns,Ns)

D. PROGRAM ORGANIZATION

1. Main Program

The main program presents a menu allowing the user to select for analysis either the open loop transfer function, the closed loop noise transfer function, the compensator transfer function, or exit the OPTGRAPH program. The data file for the selected transfer function is examined by the main program to ensure that the file contains the required transfer function data. Should the data file be incomplete the program gives the user a warning message indicating the nature of the missing data and allows the user to select another option.

The main program menu:

OPTGRAPH

DO YOU DESIRE TO ANALYZE:

1. OPEN LOOP TRANSFER FUNCTION
2. NOISE TRANSFER FUNCTION
3. COMPENSATOR TRANSFER FUNCTION
4. EXIT OPTGRAPH

ENTER OPTION NUMBER.

Data is read from the selected file by the main program and formed into three arrays and seven integer variables. The exchange of data between the main program and the subroutines, and between the subroutines is by the extensive use of labeled common statements. The data transfered through the subroutine call statements is limited primarily to flags, and constants. The program moves to its primary sequencing subroutine (GRAPH) upon the completicn of file data entry.

2. Program Sequencing

The subroutine GRAPH first presents the user with a summary cf the the transfer system received from the data file. The user is then asked which transfer function he desires to to analyze using the conventions of the OPTSYSX program describing the transfer functions by input number and output number. A menu is presented which allows the user to select graphical and/or tabular system response (Pole-Zero map, Root-locus, Bode, Nyquist, or Nichols), select another transfer function, or exit the OPTGRAPH program. Upon completion of a graphical and/or tabular response option, or change of transfer function option, the program returns to the GRAPH menu to allow the user to choose another option or exit to the main program.

Subroutine GRAPH data summary and menu:

OPTGRAPH

THE OPEN LOOP TRANSFER SYSTEM OBTAINED FROM OPTSYS CONTAINS:

1. NUMBER OF STATES = 4

```
     2.  NUMBER OF CONTROLS (INPUTS) =        1
     3.  NUMBER OF MEASUREMENTS (OUTPUTS) =   1
     4.  MARKOV PARAMETER = 10.0**- 6

          CLEAR SCREEN TO CONTINUE


                OPTGRAPH

AN OPEN LOOP POLE-ZERO, ROOT LOCUS, BODE, NYQUIST, AND/
OR NICHOLS PLOT IS DESIRED FOR:
     INPUT # ?

     OUTPUT # ?


                OPTGRAPH

OPEN LOOP TRANSFER FUNCTION
     INPUT #  =  1
     OUTPUT # =  1
DO YOU DESIRE GRAPHICAL RESPONSE AND/OR TABULAR DATA  FOR:
     1.  POLE-ZERO MAP
     2.  ROOT-LOCUS
     3.  BODE
     4.  NYQUIST (POLAR PLOT)
     5.  NICHOLS
     6.  ANOTHER INPUT/OUTPUT COMBINATION (SAME TRANSFER
         FUNCTION)
     7.  ANOTHER TYPE TRANSFER FUNCTION /EXIT OPTGRAPH
ENTER OPTION NUMBER.
```

3. Graphic and/or Tabular System Response

The selection of a graphical and/or tabular system response option for an Pole-Zero map, Root-Locus, Bode, open loop Nyquist, or open loop Nichols calls the subroutines

PZERO, RTLO, BODE, NYQST, or NICHOL respectively. While the response of these subroutines is different, their organization is similar.

The subroutines PZERO, RTLO, BODE, NYQST, and NICHOL primarily act as sequencing and plot setup subroutines. The interactive questioning of the user for graphic/tabular response information and the system response calculation has been relegated to other subroutines. The subroutines PZERO, RTLO, BODE, NYQST, and NICHOL are divided into two major sections with the first being devoted to producing a graphical output and the second to producing a tabular output.

The user is presented a subroutine menu offering the option for graphic response, tabular response, or exiting the subroutine. The program moves to either the first section (graphic response), second section (tabular response) or back to the subroutine GRAPH menu depending on the option selection. The program returns to the subroutine menu upon completion of the of either the graphic response, or tabular response section, allowing the user to select another response option, or exit the subroutine.

Features that are common to the five subroutines will be described here and features that are unique to one of the subroutines will be described in the following section under the appropriate response heading.

For a graphic response, the user is given the choice of two printer options (TEK 618, or VERSATEC). With the selection of the TEK 618, the plot page size is defaulted to 11 inches by 8.5 inches, and the plot will be presented on the TEK 618 screen. The VERSATEC option gives the user the option to create up to a 21 inch by 21 inch plot (maximum for the VERSATEC printer) and causes a DISSPLA METAFILE to be created. A scaling subroutine (PSCALE) scales the plot heading, legend, etc. in proportion to the page width selected. The VERSATEC option offers the the advantage of a

high quality print from the VERSATEC printer using the VERSATEC printer option in the OPTSYS EXEC. The creation of a DISSPLA METAFILE also gives the user (after he exits optsys) the opportunity to use printers other than the TEK 618 or VERSATEC. A major disadvantage with the VERSATEC option is that the user must exit the OPTGRAPH program before he can print a graphic system response. For this reason, it is recommended that the system response first be plotted on the TEK 618 prior to selecting the VERSATEC option.

For a tabular response,the user is presented a menu which gives him the choice of three devices (screen, printer, or disk) to send the tabular output. The user is asked if he desires to make any changes, after the tabular data has been calculated. If the answer is affirmative, he is presented a menu and allowed to make changes and rerun the tabular data routine.

Examples of these features are included in the following sections with the interactive examples for the system responses.

E. INTERACTIVE EXAMPLES

The open-loop, closed loop noise, and compensator transfer functions are are handled identically by the OPTGRAPH program, with the only difference being the program and graph headings identifying the transfer function type. The frequency response programs for the Bode, Nyquist, and Nichols responses use identical setup and tabular data routines.

A gocd overall representation of the OPTGRAPH program capabilities will be demonstrated by single interactive terminal session examples for the pole-zero, root locus, and bode responses using selected transfer functions. Tabular

data examples will be provided for the Pole-Zero, Root Locus, and Bode responses, and graphic response examples will be provided the Pole-Zero, Root Locus, Bode, Nyquist, and Nichols responses.

F. CHARACTERISTIC EQUATION ANALYSIS

The subroutines PZERO and RTLO are similar in their basic formats. The pole and zero locations for the selected transfer function input and output numbers are read into two single dimension arrays. The extraneous zeros, calculated by the OPTSYSX program, are eliminated by comparing the zeros to the Markov parameter sent with the system infcrmation from the OPTSYSX program. For a graphical response, the user is asked to define the plot limits in terms of X-coordinates (real axis) and Y-coordinates (imaginary axis). Points for the plot which fall outside these limits will be ignored. System information (tranfer function input number, output number, and (DC) gain) is listed in the graph legend.

1. Pole-Zero Map

The subroutine PZERO converts the double precision numbers for pole and zero locations to single precision for compatibility with the with the Graphics Package and plots the poles and zeros within the plot limits defined by the user for the graphical response routine. For tabular data response the user is given system information (numerator order, denominator order, and transfer function (DC) gain) for the selected transfer function input number and output number, and the pole and zero locations.

2. Pole-Zero Map (Interactive Example)

The following example of a simplified open loop transfer function for an airplane with an autopilot in the longitudinal mode was obtained from [Ref. 7,p.315].

The aircraft system is represented by:

$$[D] = [0]$$

$$[F] = \begin{bmatrix} 0. & 1. & 0. & 0. \\ 0. & 0. & 1. & 0. \\ 0. & 0. & 0. & 1. \\ 0. & 16. & -12. & -3. \end{bmatrix}$$

$$[G] = \begin{bmatrix} 0. \\ 0. \\ 1. \\ -2. \end{bmatrix}$$

$$[GAM] = [0]$$

$$[H] = [\ 1. \quad 0. \quad 0. \quad 0.\ ]$$

a. Example cf Graphic Response (Terminal Session)

```
BEGIN RECORDING OF TERMINAL SESSION
R; T=0.01/0.02 19:40:17
EXECUTION BEGINS...

                    OPTGRAPH

DO YOU DESIRE TO ANALYZE:
```

```
     1.  OPEN LOOP TRANSFER FUNCTION
     2.  NOISE TRANSFER FUNCTION
     3.  COMPENSATOR TRANSFER FUNCTION
     4.  EXIT OPTGRAPH
ENTER OPTION NUMBER.
1

                    OPTGRAPH

THE OPEN LOOP TRANSFER SYSTEM OBTAINED FROM OPTSYS
CONTAINS:
     1.  NUMBER OF STATES =                    4
     2.  NUMBER OF CONTROLS (INPUTS) =         1
     3.  NUMBER OF MEASUREMENTS (OUTPUTS) =    1
     4.  MARKOV PARAMETER = 10.0**- 6

          CLEAR SCREEN TO CONTINUE

                    OPTGRAPH

AN OPEN LOOP POLE-ZERO, ROOT LOCUS, BODE, NYQUIST,
AND? OR NICHOLS PLOT IS DESIRED FOR:
     INPUT # ?
1
     OUTPUT # ?
1

                    OPTGRAPH

OPEN LOOP TRANSFER FUNCTION
     INPUT #  =  1
     OUTPUT # =  1
DO YOU DESIRE GRAPHICAL RESPONSE AND/OR TABULAR
DATA FOR:
     1.  POLE-ZERO MAP
```

```
     2.  ROOT-LOCUS
     3.  BODE
     4.  NYQUIST (POLAR PLOT)
     5.  NICHOLS
     6.  ANOTHER INPUT/OUTPUT COMBINATION (SAME
         TRANSFER FUNCTION)
     7.  ANOTHER TYPE TRANSFER FUNCTION /EXIT
         CPTGRAPH
ENTER OPTICN NUMBER.
1


          POLE-ZERO MAP
OPEN LOOP TRANSFER FUNCTION
DO YOU DESIRE:
     1.  GRAPHICAL OUTPUT
     2.  TABULAR DATA
     3.  QUIT SUBROUTINE
ENTER OPTICN NUMBER.
1


          POLE-ZERO MAP
OPEN LOOP TRANSFER FUNCTION
PLOTTER SELECTION AND PAGE SIZE
(NOTE: PAGE IS 11.0 INCHES BY 8.5 INCHES WITH
 SELECTICN OF TEK618)
     WHICH PLOTTER DO YOU DESIRE:
          1. TEK618
          2. VERSATEC
     CHOOSE OPTION 1 OR 2
2
      PAGE SIZE (MAXIMUM = 21.0 INCHES BY 21.0
                 INCHES)
          HEIGHT =
6
```

```
          WIDTH =
8
PLOTTING LIMITS FOR GRAPH
     X AXIS (REAL AXIS)
          X MINIMUM = ?
-15
          X MAXIMUM = ?
5
     Y AXIS (IMAGINARY AXIS)
          Y MINIMUM = ?
-5
          Y MAXIMUM = ?
5

PLOTTING LIMITS FOR GRAPH
     X AXIS (REAL AXIS)
          X MINIMUM =   -15.00
          X MAXIMUM =     5.00
     Y AXIS (IMAGINARY AXIS)
           Y MINIMUM =    -5.00
           Y MAXIMUM =     5.00
DO YOU DESIRE TO MAKE ANY CHANGES ?
     TYPE "YES" OR "NO".
n

PLOT HEADING

     HOW MANY LINES OF HEADING DO YOU DESIRE ?
     ( 3MAX )
          ENTER NUMBER OF LINES.
            (ENTER "0" FOR NO HEADING)
3
     A MAXIMUM OF 32 CHARACTERS PER LINE IS
     ALLCWED
     LINE 1 IS:
aircraft with an autopilot in
```

```
     LINE 2 IS:
the longitudinal mode
     LINE 3 IS:
ref. 7; page 315

PLOT HEADING
     LINE 1 :     AIRCRAFT WITH AN AUTOPILCT IN
     LINE 2 :     THE LONGITUDINAL MODE
     LINE 3 :     REF. 7; PAGE 315
DO YOU DESIRE TO MAKE ANY CHANGES ?
     TYPE "YES" OR "NO".
n
>USING A PRE-ALLOCATED DATASET FOR UNIT FT17F001.
>USING A PRE-ALLOCATED DATASET FOR UNIT FT18F001.


          A DISSPLA METAFILE HAS BEEN CREATED
          CLEAR SCREEN TO CONTINUE


          POLE-ZERO MAP
OPEN LOOP TRANSFER FUNCTION
DO YOU DESIRE TO MAKE ANY CHANGES TO:
     1.  PLOTTER / PAGE SIZE
     2.  GRAPH LIMITS
     3.  HEADING
     4.  NO ADDITIONAL CHANGES - PLOT POLE-ZERO
         MAP
     5.  NO CHANGES - EXIT POLE-ZERO PLOTTING
         ROUTINE
ENTER OPTION NUMBER.
5


          POLE-ZERO MAP
OPEN LOOP TRANSFER FUNCTION
DO YOU DESIRE:
```

```
     1.  GRAPHICAL OUTPUT
     2.  TABULAR DATA
     3.  QUIT SUBROUTINE
ENTER OPTICN NUMBER.
3

                    OPTGRAPH

OPEN LOOP TRANSFER FUNCTION

     INPUT #  =  1
     OUTPUT # =  1
DO YOU DESIRE GRAPHICAL RESPONSE AND/OR TABULAR
DATA FOR:
     1.  POLE-ZERO MAP
     2.  ROOT-LOCUS
     3.  BODE
     4.  NYQUIST (POLAR PLOT)
     5.  NICHOLS
     6.  ANOTHER INPUT/OUTPUT COMBINATION (SAME
         TRANSFER FUNCTION)
     7.  ANOTHER TYPE TRANSFER FUNCTION /EXIT
         CPTGRAPH
ENTER OPTICN NUMBER.
7

                    OPTGRAPH

DO YOU DESIRE TO ANALYZE:
     1.  CPEN LOOP TRANSFER FUNCTION
     2.  NOISE TRANSFER FUNCTION
     3.  COMPENSATOR TRANSFER FUNCTION
     4.  EXIT OPTGRAPH
ENTER OPTICN NUMBER.
4
```

```
R; T=2.80/4.67 19:45:15
record off
END RECORDING OF TERMINAL SESSION
```

The preceding example follows at the end of the chapter as figure 3.1 .

b. Example of Tabular Data (Terminal Session)

The entering and exiting option menus for the tabular data terminal session are identical to the graphic response terminal session option menus, and have been eliminated frcm the follcwing terminal session.

```
BEGIN RECORDING OF TERMINAL SESSION
R; T=0.01/0.02 19:51:03
EXECUTION BEGINS...


          POLE-ZERO MAP
OPEN LCCP TRANSFER FUNCTION
DO YOU DESIRE:
     1.  GRAPHICAL OUTPUT
     2.  TABULAR DATA
     3.  QUIT SUBROUTINE
ENTER CPTICN NUMBER.
2


          POLE-ZERO MAP
OPEN LOCP TRANSFER FUNCTION
DO YOU DESIRE TABULAR OUTPUT TO GO TO:
     1.  SCREEN
     2.  PRINTER
     3.  DISK (OPGRAPH LISTING)
ENTER CPTICN NUMBER.
1
```

```
          POLE-ZERO MAP
OPEN LOOP TRANSFER FUNCTION
     INPUT NUMBER =       1
     OUTPUT NUMBER =      1
     TRANSFER FUNCTICN (DC) GAIN =  0.1000D+01

     DENCMINATOR ORDER =    4
POLE LOCATIONS
       REAL PART         IMAGINARY PART
       0.0000D+00        0.0000D+00
       0.1000D+01        0.0000D+00
      -0.2000D+01        0.3464D+01
      -0.2000D+01       -0.3464D+01

     NUMERATOR ORDER =    1
ZERO LOCATIONS
       REAL PART         IMAGINARY PART
      -0.1000D+01        0.0000D+00

DO YCU DESIRE TO CHANGE OUTPUT DEVICE?
     TYPE "YES" OR "NC".
n


          POLE-ZERO MAP
OPEN LOOP TRANSFER FUNCTION

DO YOU DESIRE:

     1.  GRAPHICAL OUTPUT
     2.  TABULAR DATA
     3.  QUIT SUBROUTINE

ENTER CPTICN NUMBER.
3

R; T=1.60/3.23 19:53:00
record off
```

END RECORDING OF TERMINAL SESSION

3. Root-Locus

The subroutine RTLO creates a closed loop system (with negative unity feed-back) from the selected transfer function input numbers and output numbers. Transfer function poles and zeros are formed into two separate polynomials by the subroutine MAKPOL. The numerator polynomial (zeros) is multiplied by the gains, and the two polynomials are added to form a single polynomial. Complex roots of the of the polynomial are calculated by the IMSL library subroutine ZRPCLY. The complex roots are separated into real and imaginary components for either plotting or tabulating.

The plotting routine first plots the transfer function pole and zero locations then plots the root locations as they are received from the subroutine ZRPOLY. For the plotting routine the gain interval specified by the user is divided into 2000 evenly spaced points for the subroutine ZRPOLY to calculate roots. The poles, zeros, and roots are plotted within the plot limits specified by the user.

For the tabular data routine the user is given the option to choose between 1 and 500 points for the subroutine ZRPOLY to calculate roots. The tabular data output provided for the user is system information (numerator order, denominator order, and transfer function (DC) gain) for the selected transfer function input number and output number, the pole and zero locations, and the root locus gains and roots

A positive unity feedback system may be analyzed by specifying a negative gain range vice a positive gain range.

4. Root-Locus (Interactive Example)

The following interactive example is of the open loop transfer function for an aircraft with an autopilot in the longitudinal mode described in Pole-Zero interactive section.

a. Example of Graphic Response (Terminal Session)

```
BEGIN RECORDING OF TERMINAL SESSION
R; T=0.01/0.02 20:28:37
EXECUTION BEGINS...

                OPTGRAPH

DO YOU DESIRE TO ANALYZE:
     1.  OPEN LOOP TRANSFER FUNCTION
     2.  NOISE TRANSFER FUNCTION
     3.  COMPENSATOR TRANSFER FUNCTION
     4.  EXIT OPTGRAPH
ENTER OPTION NUMBER.
1

                OPTGRAPH

THE OPEN LOOP TRANSFER SYSTEM OBTAINED FROM OPTSYS
CONTAINS:
     1.  NUMBER OF STATES =                    4
     2.  NUMBER OF CONTROLS (INPUTS) =         1
     3.  NUMBER OF MEASUREMENTS (OUTPUTS) =    1
     4.  MARKOV PARAMETER = 10.0**- 6

          CLEAR SCREEN TO CONTINUE

                OPTGRAPH

AN OPEN LOOP POLE-ZERO, ROOT LOCUS, BODE, NYQUIST,
```

```
AND/OR NICHOLS PLOT IS DESIRED FOR:
     INPUT # ?
1
     OUTPUT # ?
1


               OPTGRAPH

OPEN LOOP TRANSFER FUNCTION
     INPUT #  =  1
     OUTPUT # =  1
DO YOU DESIRE GRAPHICAL RESPONSE AND/OR TABULAR
DATA FOR:
     1.  POLE-ZERO MAP
     2.  ROOT-LOCUS
     3.  BODE
     4.  NYQUIST (POLAR PLOT)
     5.  NICHOLS
     6.  ANOTHER INPUT/OUTPUT COMBINATION (SAME
         TRANSFER FUNCTION)
     7.  ANOTHER TYPE TRANSFER FUNCTION /EXIT
         OPTGRAPH
ENTER OPTION NUMBER.
2


          ROOT-LOCUS
OPEN LOOP TRANSFER FUNCTION
DO YOU DESIRE:
     1.  GRAPHICAL OUTPUT
     2.  TABULAR DATA
     3.  QUIT SUBROUTINE
ENTER OPTION NUMBER.
1
```

```
          ROOT-LOCUS
OPEN LOOP TRANSFER FUNCTION
PLOTTER SELECTION AND PAGE SIZE
(NOTE: PAGE IS 11.0 INCHES BY 8.5 INCHES WITH
 SELECTION OF TEK618)

     WHICH PLOTTER DO YOU DESIRE:
          1. TEK618
          2. VERSATEC
     CHOOSE OPTION 1 OR 2
2
      PAGE SIZE (MAXIMUM = 21.0 INCHES BY 21.0
                 INCHES)
          HEIGHT =
6
          WIDTH =
8


PLOTTING LIMITS FOR GRAPH
     X AXIS (REAL AXIS)
          X MINIMUM = ?
-15
          X MAXIMUM = ?
5
     Y AXIS (IMAGINARY AXIS)
          Y MINIMUM = ?
-5
          Y MAXIMUM = ?
5

PLOTTING LIMITS FOR GRAPH
     X AXIS (REAL AXIS)
          X MINIMUM =   -15.00
          X MAXIMUM =     5.00
     Y AXIS (IMAGINARY AXIS)
```

```
          Y MINIMUM =    -5.00
          Y MAXIMUM =     5.00
DO YCU DESIRE TO MAKE ANY CHANGES ?
     TYPE "YES" OR "NC".
n


GAIN RANGE FOR ROOT-LCCUS PLOT
          MINIMUM GAIN = ?
0
          MAXIMUM GAIN = ?
500

GAIN RANGE FOR ROOT-LCCUS PLOT
          MINIMUM GAIN =       0.000D+00
          MAXIMUM GAIN =       0.500D+03
DO YOU DESIRE TO MAKE ANY CHANGES ?
     TYPE "YES" OR "NO".
n


PLOT HEADING
     HOW MANY LINES OF HEADING DO YOU DESIRE ?
     ( 3 MAX )
          ENTER NUMBER OF LINES.
          (ENTER "0" FOR NO HEADING)
3
     A MAXIMUM OF 32 CHARACTERS PER LINE IS
     ALLOWED
     LINE 1 IS:
aircraft with an autopilot in
     LINE 2 IS:
the longitudinal mode
     LINE 3 IS:
ref. 7; page 315

PLOT HEADING
```

```
     LINE 1 :      AIRCRAFT WITH AN AUTOPILOT IN
     LINE 2 :      THE LONGITUDINAL MODE
     LINE 3 :      REF. 7; PAGE 315
DO YOU DESIRE TO MAKE ANY CHANGES ?
     TYPE "YES" OR "NO".
n
>USING A PRE-ALLOCATED DATASET FOR UNIT FT17F001.
>USING A PRE-ALLOCATED DATASET FOR UNIT FT18F001.

          A DISSPLA METAFILE HAS BEEN CREATED
          CLEAR SCREEN TO CONTINUE


          ROOT-LOCUS
OPEN LOOP TRANSFER FUNCTION
DO YOU DESIRE TO MAKE ANY CHANGES TO:
     1.  PLOTTER / PAGE SIZE
     2.  GRAPH LIMITS
     3.  HEADING
     4.  GAIN RANGE
     5.  NO ADDITIONAL CHANGES - PLOT ROOT-LOCUS
     6.  NO CHANGES - EXIT ROOT-LOCUS PLOTTING
         ROUTINE
ENTER OPTION NUMBER.
6


          ROOT-LOCUS
OPEN LOOP TRANSFER FUNCTION
DO YOU DESIRE:
     1.  GRAPHICAL OUTPUT
     2.  TABULAR DATA
     3.  QUIT SUBROUTINE
ENTER OPTION NUMBER.
3
```

```
                OPTGRAPH

OPEN LOOP TRANSFER FUNCTION
     INPUT #  =  1
     OUTPUT # =  1
DO YOU DESIRE GRAPHICAL RESPONSE AND/OR TABULAR
DATA FOR:
     1.  POLE-ZERO MAP
     2.  ROOT-LOCUS
     3.  BODE
     4.  NYQUIST (POLAR PLOT)
     5.  NICHOLS
     6.  ANOTHER INPUT/OUTPUT COMBINATION (SAME
         TRANSFER FUNCTION)
     7.  ANOTHER TYPE TRANSFER FUNCTION /EXIT
         OPTGRAPH
ENTER OPTION NUMBER.
7

                OPTGRAPH

DO YOU DESIRE TO ANALYZE:
     1.  OPEN LOOP TRANSFER FUNCTION
     2.  NOISE TRANSFER FUNCTION
     3.  COMPENSATOR TRANSFER FUNCTION
     4.  EXIT OPTGRAPH
ENTER OPTION NUMBER.
4
R; T=12.36/15.14 20:32:54
record off
END RECORDING OF TERMINAL SESSION
```

The preceding example follows at the end of the chapter as figure 3.2 .

b. Example of tabular data (Terminal Session)

The entering and exiting option menus for the tabular data terminal session are identical to the graphic response terminal session option menus, and have been eliminated from the following terminal session.

```
BEGIN RECORDING OF TERMINAL SESSION
R; T=0.01/0.02 20:42:59
EXECUTION BEGINS...


        ROOT-LOCUS
OPEN LOOP TRANSFER FUNCTION
DO YOU DESIRE:
     1.  GRAPHICAL OUTPUT
     2.  TABULAR DATA
     3.  QUIT SUBROUTINE
ENTER OPTION NUMBER.
2

         ROOT-LOCUS
OPEN LOOP TRANSFER FUNCTION
DO YOU DESIRE TABULAR OUTPUT TO GO TO:
     1.  SCREEN
     2.  PRINTER
     3.  DISK (OPGRAPH LISTING)
ENTER OPTION NUMBER.
1

GAIN RANGE FOR ROOT-LOCUS PLOT
         MINIMUM GAIN = ?
1
         MAXIMUM GAIN = ?
5
```

```
GAIN RANGE FOR ROOT-LCCUS PLOT
          MINIMUM GAIN =       0.100D+01
          MAXIMUM GAIN =       0.500D+01
DO YOU DESIRE TO MAKE ANY CHANGES ?
     TYPE "YES" OR "NC".
n
HOW MANY PCINTS DO YOU WANT TO TABULATE?
     (500 IS THE MAXIMUM)
ENTER NUMBER OF POINTS.
5

          ROOT-LOCUS
OPEN LOOP TRANSFER FUNCTION
     INPUT NUMBER =       1
     CUTPUT NUMBER =      1
     TRANSFER FUNCTICN (DC) GAIN =  0.1000D+01
OPEN ICOP TF POLES AND ZEROS

     DENCMINATOR ORDER =    4
     POLE LOCATIONS
       REAL PART         IMAGINARY PART
       0.0000D+00        0.0000D+00
       0.1000D+01        0.0000D+00
      -0.2000D+01        0.3464D+01
      -0.2000D+01       -0.3464D+01

     NUMERATOR ORDER =    1
     ZERO LOCATIONS
       REAL PART         IMAGINARY PART
      -0.1000D+01        0.0000D+00

     GAIN =   0.1000D+01
       REAL PART         IMAGINARY PART
       0.7074D-01        0.0000D+00
       0.8962D+00        0.0000D+00
      -0.1983D+01        0.3441D+01
```

```
 -0.1983D+01      -0.3441D+01

GAIN =   0.1800D+01
  REAL PART         IMAGINARY PART
  0.1453D+00         0.0000D+00
  0.7948D+00         0.0000D+00
 -0.1970D+01         0.3422D+01
 -0.1970D+01        -0.3422D+01

GAIN =   0.2600D+01
  REAL PART         IMAGINARY PART
  0.2576D+00         0.0000D+00
  0.6552D+00         0.0000D+00
 -0.1956D+01         0.3402D+01
 -0.1956D+01        -0.3402D+01

GAIN =   0.3400D+01
  REAL PART         IMAGINARY PART
  0.4426D+00         0.1661D+00
  0.4426D+00        -0.1661D+00
 -0.1943D+01         0.3383D+01
 -0.1943D+01        -0.3383D+01

GAIN =   0.4200D+01
  REAL PART         IMAGINARY PART
  0.4285D+00         0.3096D+00
  0.4285D+00        -0.3096D+00
 -0.1929D+01         0.3363D+01
 -0.1929D+01        -0.3363D+01
DO YCU DESIRE TO MAKE ANY CHANGES ?
     TYPE "YES" OR "NO".
Y

          ROOT-LOCUS
OPEN ICCP TRANSFER FUNCTION
DO YOU DESIRE TO MAKE ANY CHANGES TO:
     1.  OUTPUT DEVICE
```

```
     2.  GAIN RANGE
     3.  NUMBER OF POINTS CALCULATED
     4.  NO ADDITIONAL CHANGES - TABULATE DATA
     5.  EXIT ROOT-LOCUS TABULAR DATA ROUTINE
ENTER OPTION NUMBER.
5

          ROOT-LOCUS
OPEN LOOP TRANSFER FUNCTION
DO YOU DESIRE:
     1.  GRAPHICAL OUTPUT
     2.  TABULAR DATA
     3.  QUIT SUBROUTINE
ENTER OPTION NUMBER.
3

R; T=1.63/3.40 20:44:54
record off
END RECORDING OF TERMINAL SESSION
```

G. FREQUENCY RESPONSE ANALYSIS

The calculations for the frequency response of the Bode, Nyquist, and Nichols responses are identical. The only difference is in the graphical presentation of the calculated data. The subroutines BODE, NYQST, and NICHOLS call the subroutine FREQ to calculate the transfer function magnitude and phase for the frequency range specified by the user.

The subroutine FREQ eliminates the extraneous zeros by comparing the zeros to the Markov parameter as described in the Characteristic Equation Analysis section. The frequency response magnitude and phase are calculated using double precision complex library functions following the

conventions of the IBM System /360/370/ FORTRAN IV language. The frequency response is calculated by determining the product of successive numerator zeros which have been combined with the frequency and divided by the prcduct of successive denominatcr poles which also have been combined with the frequency. The magnitude for the complex result of the zeros, poles, and frequency calculations is determined using the FORTRAN dcuble precision library functions for finding the magnitude of a complex argument. The phase of the of the complex result is determined by separating the real and imaginary parts of the complex results, and finding the phase angle using the double precision FORTRAN library function arctangent. The angle is converted from radians to degrees and is corrected for proper quadrant by checking the signs of the real and imaginary parts. The normal range for calculating phase angles by the subroutine is from +540 degrees to -540 degrees. This range is considered adequate for most application, but should these limits be exceeded the plot will jump with a vertical line to either +360 degrees or -360 degrees respectively before continuing with the plot.

For a graphic response the user specified frequency range is divided into 500 equally spaced points (on a logrithmic scale) for which to calculate the magnitude and phase. The user is given the option to select between 1 and 500 points for tabular data.

1. Bode Response

The graphic response section of the subroutine BODE creates two plots. The first plot is the response magnitude in decibels versus the frequency in radians per second. The magnitude from the subroutine FREQ is converted to decibels and plotted with its corresponding frequency. The second plot is of the phase in degrees versus frequency in radians

per second. The phase from the subroutine FREQ is plotted with its corresponding frequency. The frequency for both plots is plotted on a logrithmic scale. The scale range for both is set automatically to include the entire range of data to be plotted by the subroutine MINMAX which scans the data for the maximum and minimum values. System information (tranfer function input number, output number, and (DC) gain) is listed in the graph legend.

The magnitude in decibels and the phase in degrees is searched for "0" decibel and 180 degree crossover points to calculate the phase and gain margins.

The tabular response section gives the user the option to select the the number of frequency points to be calculated between 1 and 500 for the frequency range he has specified. For tabular data response the user is given system information (numerator order, denominator order, and transfer function (DC) gain) for the selected transfer function input number and output number, and the frequency (radians per second), magnitude (decibels), phase (degrees), and the real and imaginary frequency response parts.

2. Bode Response (Interactive Example)

The following example of compensator transfer function with a filter and regulator was obtained from [Ref. 8,pp. 382 - 384].

The compensated system is represented by:

$$[C] = [\ -254.1 \quad -19.57\ ]$$

$$[D] = [0]$$

$$[F] = \begin{vmatrix} 0. & 1.0 \\ 0. & -4.6 \end{vmatrix}$$

$$[G] = \begin{vmatrix} 0. \\ 0.787 \end{vmatrix}$$

$$[GAM] = \begin{vmatrix} 0. \\ 0.1 \end{vmatrix}$$

$$[H] = [\ 1.\ \ 0.\ ]$$

$$[K] = \begin{vmatrix} 95.4 \\ 4561. \end{vmatrix}$$

$$[Q] = [10.]$$

a. Example cf Graphic Response (Terminal Session)

```
BEGIN RECCRDING OF TERMINAL SESSION
R; T=0.01/0.02 18:30:23
graphics
EXECUTION BEGINS...

                OPTGRAPH

DO YOU DESIRE TO ANALYZE:
     1.  OPEN LOOP TRANSFER FUNCTION
     2.  NOISE TRANSFER FUNCTION
     3.  COMPENSATOR TRANSFER FUNCTION
     4.  EXIT OPTGRAPH
ENTER OPTION NUMBER.
3

                OPTGRAPH
```

```
THE COMPENSATOR TRANSFER SYSTEM OBTAINED FROM
OPTSYS CONTAINS:
     1.  NUMBER OF STATES =                    2
     2.  NUMBER OF CONTROLS (INPUTS) =         1
     3.  NUMBER OF MEASUREMENTS (OUTPUTS) =    1
     4.  MARKOV PARAMETER = 10.0**- 6

          CLEAR SCREEN TO CONTINUE


                    OPTGRAPH

AN OPEN LOOP POLE-ZERO, ROOT LOCUS, BODE, NYQUIST,
AND/OR NICHOLS PLOT IS DESIRED FOR:
          INPUT # ?
1
          OUTPUT # ?
1


                    OPTGRAPH

COMPENSATOR TRANSFER FUNCTION
     INPUT #  =  1
     OUTPUT # =  1
DO YOU DESIRE GRAPHICAL RESPONSE AND/OR TABULAR
DATA FOR:
     1.  POLE-ZERO MAP
     2.  ROOT-LOCUS
     3.  BODE
     4.  NYQUIST (POLAR PLOT)
     5.  NICHOLS
     6.  ANOTHER INPUT/OUTPUT COMBINATION (SAME
         TRANSFER FUNCTION)
     7.  ANOTHER TYPE TRANSFER FUNCTION /EXIT
         OPTGRAPH
ENTER OPTION NUMBER.
```

```
3

          BODE PLOT
COMPENSATCR TRANSFER FUNCTION
DO YOU DESIRE:
     1.  GRAPHICAL OUTPUT
     2.  TABULAR DATA
     3.  QUIT SUBROUTINE
ENTER OPTICN NUMBER.
1

          BODE PLOT
COMPENSATCR TRANSFER FUNCTION
PLOTTER SELECTION AND PAGE SIZE
(NOTE: PAGE IS 11.0 INCHES BY 8.5 INCHES WITH
 SELECTICN OF TEK618)
     WHICH PLOTTER DO YOU DESIRE:
          1. TEK618
          2. VERSATEC
     CHOCSE OPTION 1 OR 2
2
     PAGE SIZE (MAXIMUM = 21.0 INCHES BY 21.0
                INCHES)
          HEIGHT =
5.65
          WIDTH =
8.5

PLOTTING LIMITS FOR GRAPH
     FREQUENCY RANGE - RADIANS PER SECOND
          MINIMUM FREQUENCY = ?
0.1
          MAXIMUM FREQUENCY = ?
1000000

PLOTTING LIMITS FOR GRAPH
     FREQUENCY RANGE - RADIANS PER SECONC
```

```
          MINIMUM FREQUENCY =       0.100E+00
          MAXIMUM FREQUENCY =       0.100E+07
DO YOU DESIRE TO MAKE ANY CHANGES ?
     TYPE "YES" OR "NO".
n

PLOT HEADING
     HOW MANY LINES OF HEADING DO YOU DESIRE ?
     ( 3 MAX )
          ENTER NUMBER OF LINES.
            ( ENTER "0" FOR NO HEADING )
2
     A MAXIMUM OF 32 CHARACTERS PER LINE IS
     ALLCWED
     LINE 1 IS:
filter simulation
     LINE 2 IS:
ref. 8; pages 332 - 334

PLOT HEADING
     LINE 1 :     FILTER SIMULATION
     LINE 2 :     REF. 8; PAGES 332 - 334
DO YOU DESIRE TO MAKE ANY CHANGES ?
     TYPE "YES" OR "NO".
n


          A DISSPLA METAFILE HAS BEEN CREATED
          CLEAR SCREEN TO CONTINUE


          GAIN MARGIN AND PHASE MARGIN
PHASE CROSSOVER FREQUENCY IS   75.1184 RAD/SEC;
         GAIN MARGIN IS   -59.8906 DB
GAIN CROSSOVER FREQUENCY IS ********** RAD/SEC;
         PHASE MARGIN IS  -89.9480 DEG
          CLEAR SCREEN TO CONTINUE
```

```
          BODE PLOT
COMPENSATOR TRANSFER FUNCTION
DO YOU DESIRE TO MAKE ANY CHANGES TO:
     1.  PLOTTER / PAGE SIZE
     2.  GRAPH LIMITS (FREQUENCY RANGE)
     3.  HEADING
     4.  NO ADDITIONAL CHANGES - PLOT BODE PLOTS
     5.  NO CHANGES - EXIT BODE SUBROUTINE
ENTER OPTION NUMBER.
5

          BODE PLOT
COMPENSATOR TRANSFER FUNCTION
DO YOU DESIRE:
     1.  GRAPHICAL OUTPUT
     2.  TABULAR DATA
     3.  QUIT SUBROUTINE
ENTER OPTION NUMBER.
3


               OPTGRAPH

COMPENSATOR TRANSFER FUNCTION
     INPUT #  =  1
     OUTPUT # =  1
DO YOU DESIRE GRAPHICAL RESPONSE AND/OR TABULAR
DATA FOR:
     1.  POLE-ZERO MAP
     2.  ROOT-LOCUS
     3.  BODE
     4.  NYQUIST (POLAR PLOT)
     5.  NICHOLS
     6.  ANOTHER INPUT/OUTPUT COMBINATION (SAME
```

```
                TRANSFER FUNCTION)
          7.    ANOTHER TYPE TRANSFER FUNCTION /EXIT
                CPTGRAPH
ENTER OPTION NUMBER.
7


                    OPTGRAPH

DO YOU DESIRE TO ANALYZE:
          1.    OPEN LOOP TRANSFER FUNCTION
          2.    NOISE TRANSFER FUNCTION
          3.    COMPENSATOR TRANSFER FUNCTION
          4.    EXIT OPTGRAPH
ENTER OPTION NUMBER.
4
R; T=7.01/8.84 18:39:11
record off
END RECORDING OF TERMINAL SESSION
```

The preceding example follows at the end of the chapter as figure 3.3 and figure 3.4 .

b. Example of Tabular Data Listing File

The terminal session for the Bode tabular data response is similar to the Bode graphic response terminal session. Appendix D contains an example of tabular output sent to a disk (OPGRAPH LISTING) for five points between 10 and 100 radians/second.

3. Nyquist Response

The graphic response section of the subroutine NYQST creates a polar plot from the magnitude and phase data received from the subroutine FREQ. The plot is automatically scaled from a minimum radius of one by using the

subroutine MINMAX to determine the maximum phase and magnitude values. The gain / phase margin calculations and the tabular data output are identical to the subroutine BODE.

4. Nyquist Response (Interactive Example)

The following example is of the open loop transfer function for the filter simulation example described in the Bode interactive section.

This example follows at the end of the chapter as figure 3.5 .

5. Nichols Response

The graphic response section of the subroutine NICHCI creates a single rectangular plot of magnitude in decibels versus phase in degrees. The magnitude from the subroutine FREQ is converted to decibels and plotted with the corresponding magnitude. The plot is automatically scaled using the subroutine MINMAX to determine the maximum phase and magnitude values. The gain / phase margin calculations and the tabular data output are identical to the subroutine BODE.

6. Nichols Response (Interactive Example)

The following example is of the open loop transfer function for the filter simulation example described in the Bode interactive section.

This example follows at the end of the chapter as figure 3.6 .

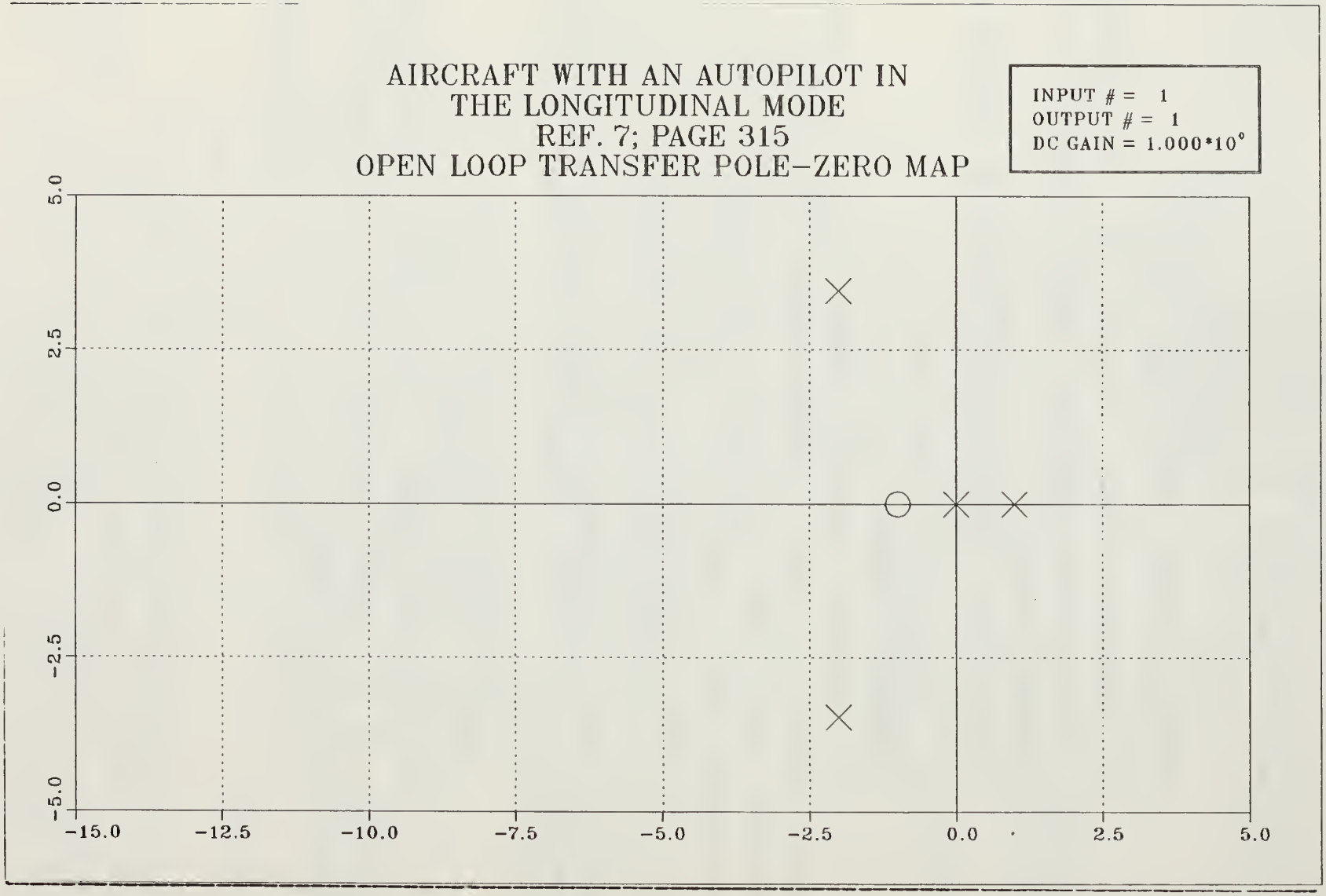

Figure 3.1 Pole-Zero Map Example.

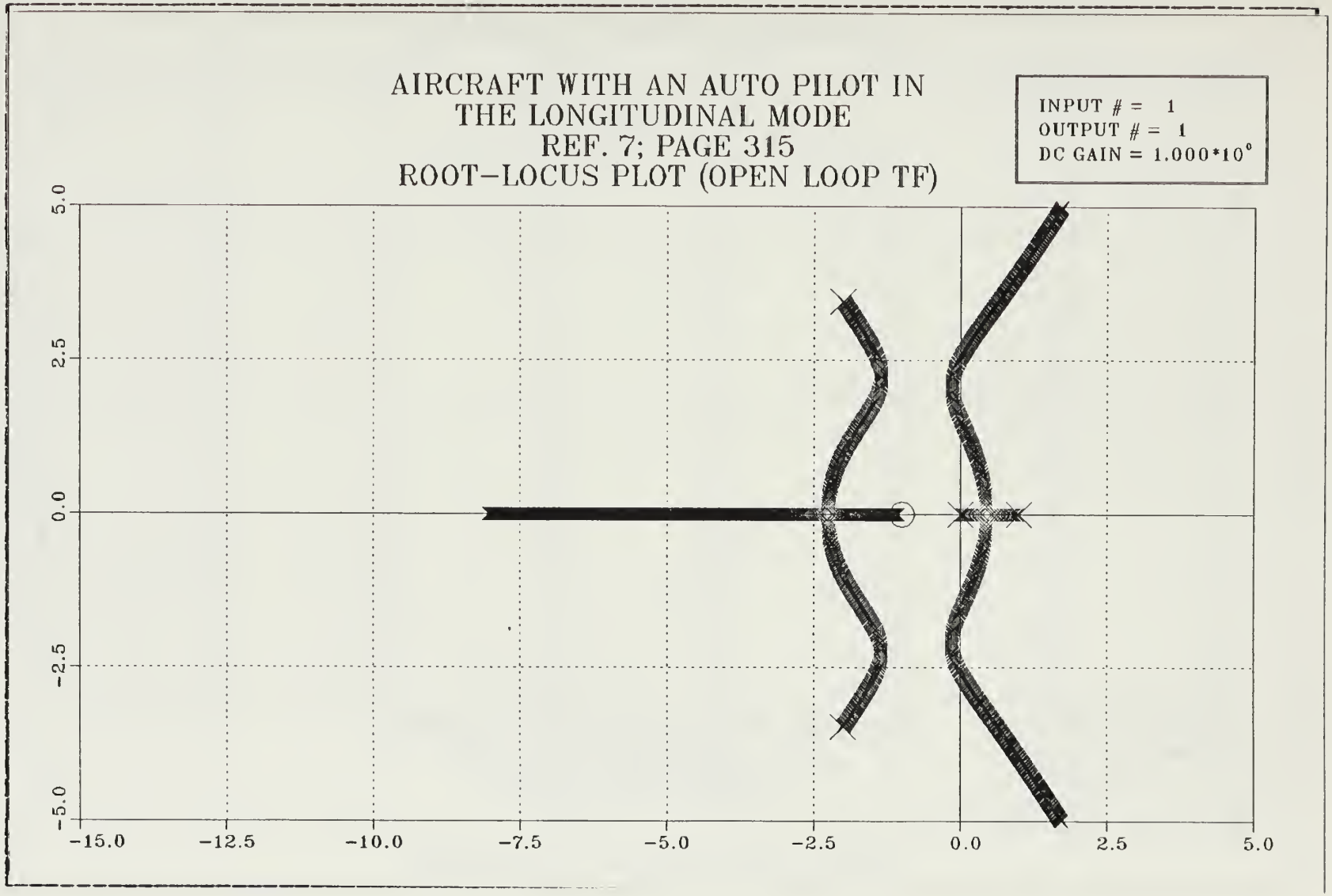

Figure 3.2 Root Locus Response Example.

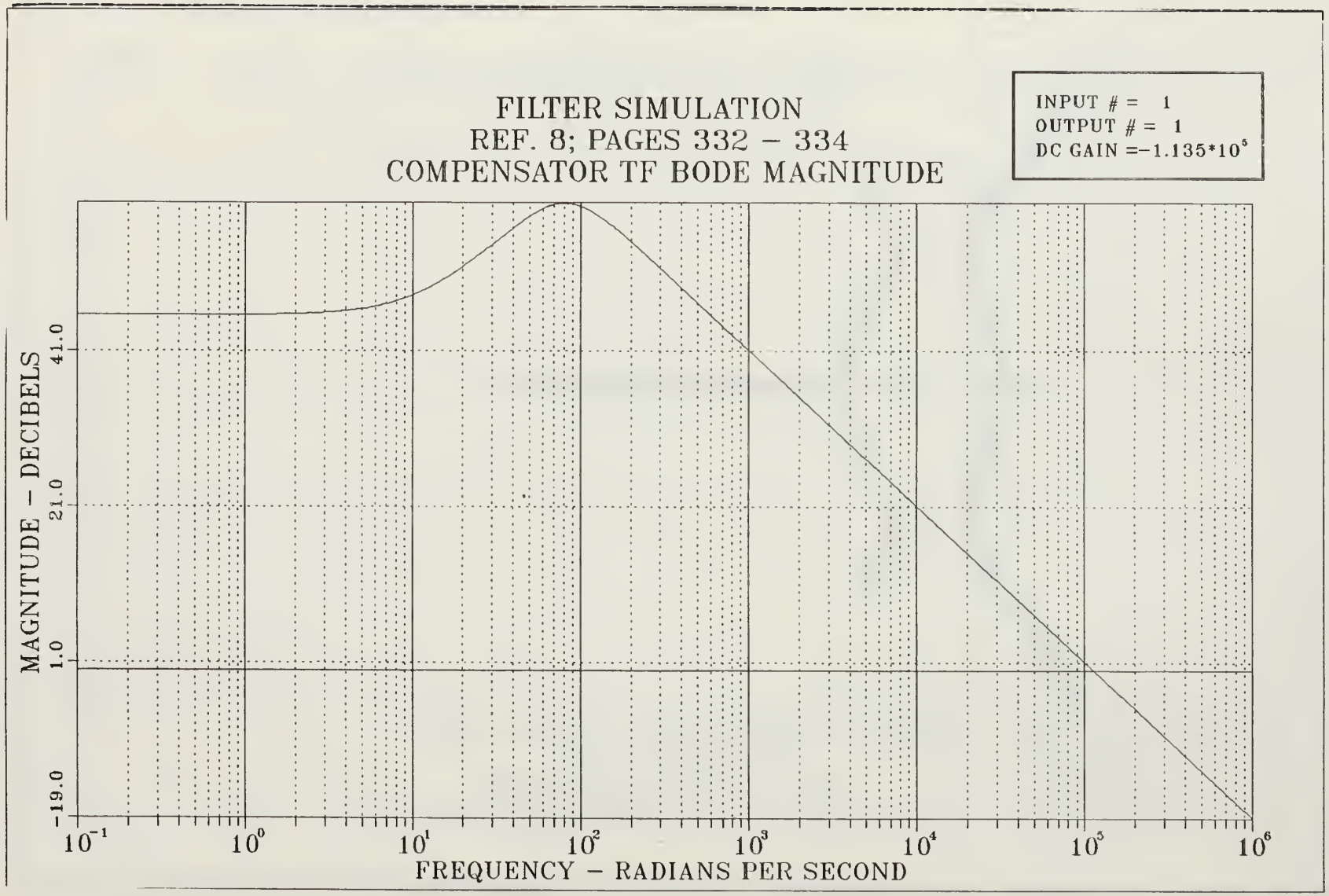

Figure 3.3 Bode Response Example (Magnitude).

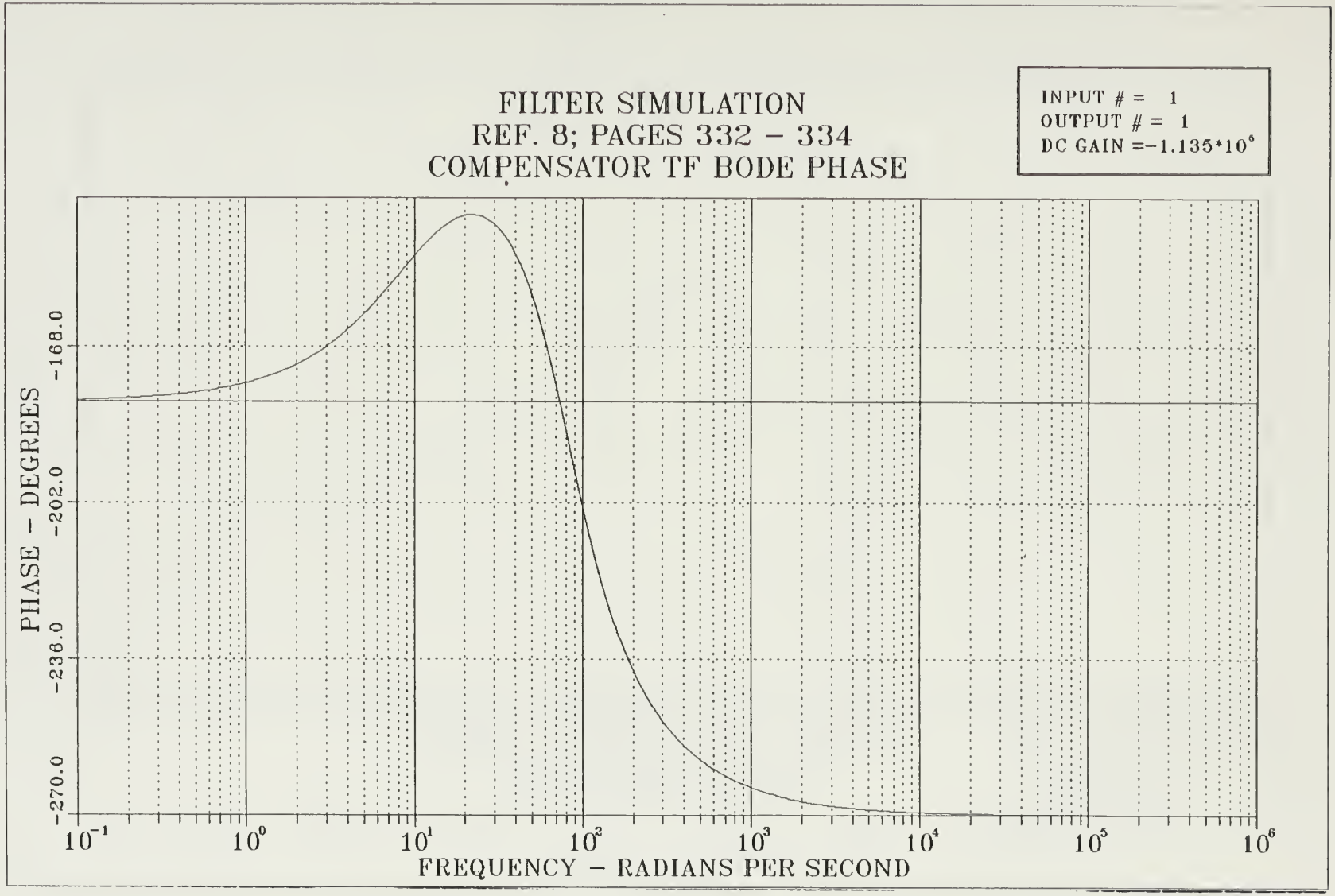

Figure 3.4 Bode Response Example (Phase).

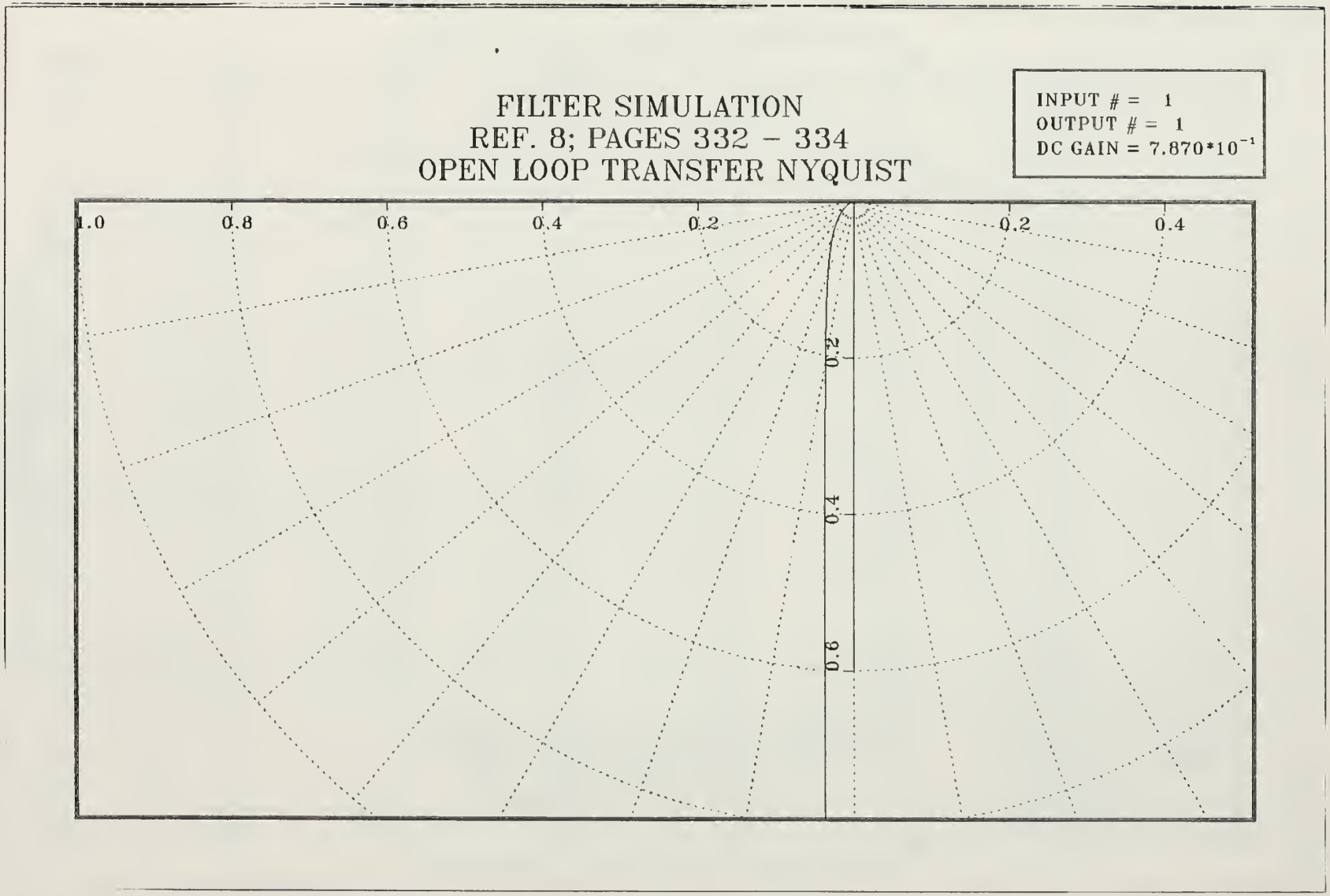

Figure 3.5 Nyquist Response Example.

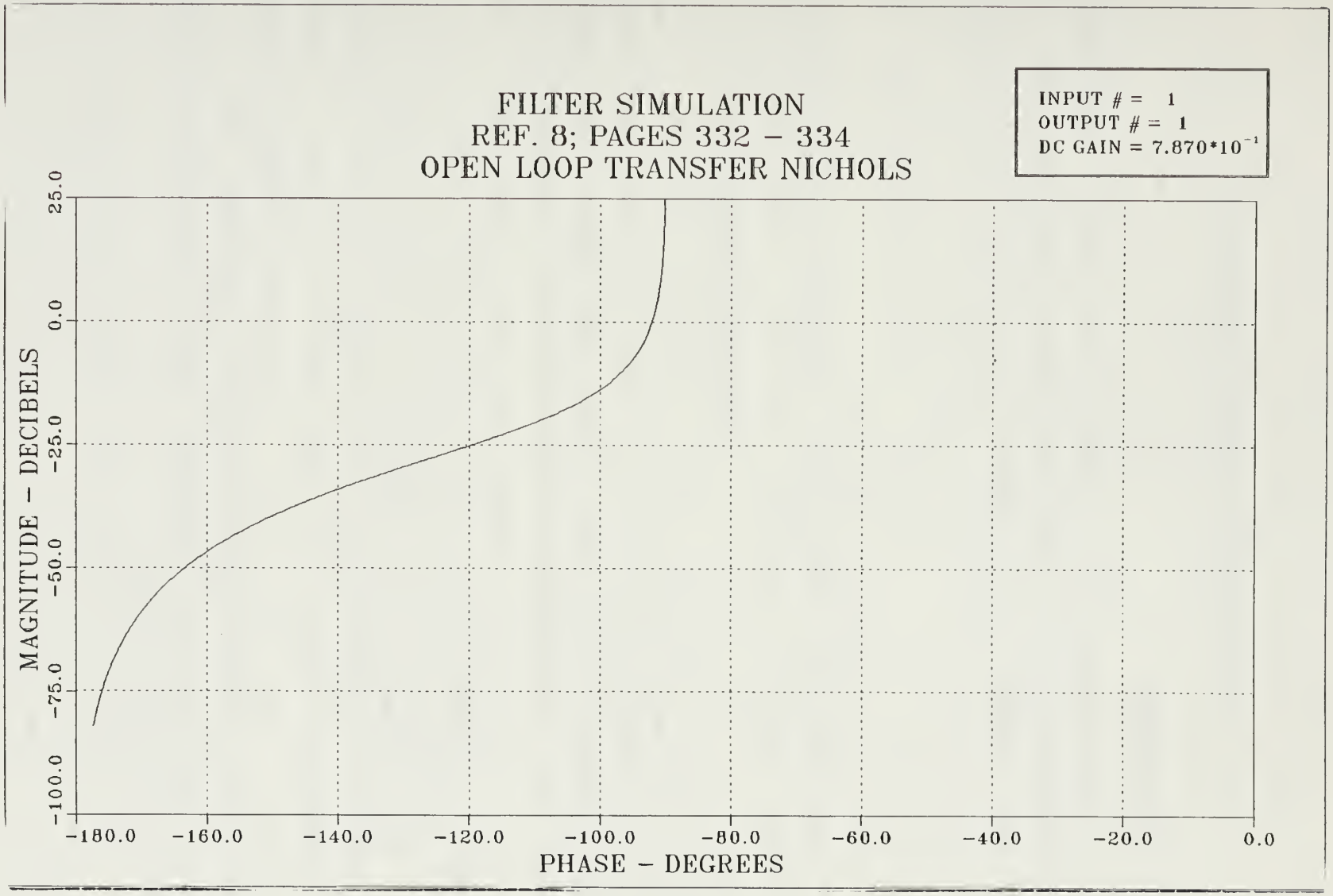

Figure 3.6 Nichols Response Example.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

An evaluation of the computational ability of OPTSYSX and OPTGRAPH, the program was tested using an 82 X 82 matrix, provided by NASA-Edwards, of longitudinal equations for the X-29A experimental forward-swept wing fighter aircraft prototype. The OPTSYSX program array had to be redimensioned and a 2-megabyte virtual machine size was required for a system of this size.

The open loop eigenvalues calculated by the OPTSYSX program compared favorably with the Eigensystem data supplied by NASA-Edwards, but the OPTSYSX program failed in calculating the open loop transfer function zeros. Extraneous zeros (calculated by OPTSYSX) were of the same approximate magnitude as the open loop system zeros. This prevented the identification and elimination of the extraneous zeros by comparison with the Markov parameter. The open loop zero identification was further complicated by not having available open loop transfer function zero information from NASA-Edwards to compare the OPTSYSX results to.

When requested for additional information NASA-Edwards provided a computer tape with a revised 98 X 98 matrix of longitudinal motion equations for the X-29A fighter aircraft. For this revised system, the OPTSYSX program requires a virtual machine size in excess of 2-megabyte. Time constraints have prevented running the OPTSYSX program with the revised system.

The OPTGRAPH program was tested using the OPTSYSX program's open loop Eigenvalue and transfer function output data for the X-29A 82 X 82 system of longitudinal motion

equations. OPTGRAPH provided excellent quality Bode plots for all of the open loop transfer function inputs and outputs and did not exhibit any computational difficulties as indicated by the lack of error messages at the end of the test. While the test results are encouraging as to the ability of the OPTGRAPH program to assist in the analysis of large order systems, the actual computational accuracy of the OPTGRAPH program can not be fully verified until accurate transfer function information can be obtained from the OPTSYSX program.

B. RECOMMENDATIONS

Based on the results of this Thesis the following areas emerged as possible areas for further research and study.

1. Root Finding Routines

The OPTSYSX program has two similar root finding subroutines (HQR and HQR2), to find the transfer function Eigensystem (poles) and zeros. The order of the transfer function numerator is calculated separately in the subroutine ZEROS.

The inclusion of the open loop transfer function eigensystem (pole locations), zero locations, transfer function numerator orders, and transfer function gains, for the revised (98 X 98) longitudinal mode system by NASA-Edwards should simplify the locating the problem in calculating the transfer function zeros.

The open loop system data from NASA-Edwards also included Bode magnitude and phase plots, and gain and phase margin information, which can be used to evaluate more conclusively the OPTGRAPH program's ability to help evaluate a large order system.

2. Program Memory Requirements

The OPTSYSX program requires in excess of 2-megabyte of virtual machine memory when configured for large matrix operations (98 X 98). Virtual machines with this memory capacity are not normally available to a user. The memory usage for matrix storage and manipulation is a possible area for the reduction in program memory requirement size. The OPTSYSX program retains most of its computational arrays in memory. This method simplifies programming but is extremely inefficient in its use of virtual machine memory.

3. Further Modifications

The area of modern digital controls should be further investigated. The computational abilities of the OPTGRAPH program make it readily adaptable, with minor modifications, for assisting in the analysis of transfer functions in the digital domains.

APPENDIX A
OPTSYS EXEC LISTING

```
    &TRACE OFF
*************************************************************
*                      THE OPTSYS EXEC
*           CONTROLS THE OPTSYSX, OPTCALC AND OPTPLOT
*           TO DETERMINE THE TIME RESPONSE OF A SYSTEM.
*                        BY H. A. DIEL
*                   VERSION 1.0   16 JULY 1984
*                    MODIFIED BY M. H. LAPTAS
*************************************************************
CLRSCRN
&BEGTYPE -ENDFOUR



*************************************************************

      OUTPUT FROM OPTSYSX WILL COME TO THE SCREEN IF YOU
               WISH DISK FILE
               ENTER  D    ANY OTHER INPUT YIELD SCREEN

*************************************************************

-ENDFOUR
&READ VARS &ANS
&IF .&ANS NE .D &GOTO -ONE
FILEDEF 06 DISK OUTPUTX LISTING A1
CLRSCRN
&BEGTYPE -ENDSIX
```

```
************************************************************

        OUTPUT WILL GO TO DISK FILE 'OUTPUTX LISTING A1'

************************************************************

-ENDSIX
CP SLEEP 3 SEC
-ONE
CLRSCRN
CP LINK 0039P 191 251 RR
ACC 251 F
************************************************************
*                                                          *
*      ALLOW THE USE OF AN OLD "OPTMAT DATA A1"            *
*                                                          *
************************************************************
RENAME OPTMAT DATA A1 OPTSYS DATA A1
&IF &RC NE 0 &GOTO -FIRST
RENAME OPTSYS DATA A1 OPTMAT DATA A1
FINDSTAK OPTMAT DATA A1 C01 0 LIM002 ALL GROUP1
&READ VARS &A1 &A2
&IF .&A2 NE .1 &GOTO -START
CLRSCRN
&BEGTYPE -ENDTWO


************************************************************

     YOU HAVE A DATA FILE NAMED 'OPTMAT DATA' ON YOUR A
     DISK  THAT WAS PREVIOUSLY GENERATED BY THE  OPTSYS
     PROGRAM  AND  CONTAINS THE F, G, H, GAMMA, A AND B
     MATRICES FROM THAT RUN.
```

```
     IF  YOU WOULD LIKE TO USE THESE SAME MATRICES  FOR
     THIS  RUN, THE  CPTSYS  PROGRAM  WILL  READ IN THE
     DESIRED DATA AT THE APPROPRIATE TIME,

                    IF YOU TYPE (Y)ES.

     ANY OTHER INPUT WILL RESULT IN THAT FILE BEING ERASED!

************************************************************
-ENDTWO
&READ VARS &ANS
&IF .&ANS EQ .Y &GOTO -START
-FIRST
************************************************************
*                                                          *
*      ERASE THE OLD "OPTMAT DATA A1" DATA FILE            *
*     PLACE "000 0" IN THE NEW "OPTMAT DATA FILE"          *
*     TO ACT AS A FLAG FOR OPTSYSX  AND OPTCALC            *
*                                                          *
************************************************************
ERASE OPTMAT DATA A1
&STACK 000 0
FILESTCK OPTMAT DATA A1 F 80 1
-START
CLRSCRN
&BEGTYPE -ENDONE


      THE OPTSYS EXEC CONTROLS FOUR PROGRAMS:

         1  OPTSYSX FORTRAN  (SYSTEM ANALYSIS)
              GENERATES OPTMAT AND OPTGRAPH DATA SETS
              - RERUN USES OPTMAT
         2  OPTCALC FORTRAN  (CALCULATE TIME RESPONSE)
              GENERATES OPTPLOT DATA SET  USES OPTMAT FROM
              OPTSYSX
         3  OPTGRAPH FORTRAN  (POLE-ZERO, ROOT-LOCUS, BODE,
```

```
            NYQUIST, ETC)
              USES OPTGROL -OPTGRNO -OPTGRCM FROM OPTSYSX
         4  EXIT

           OPTPLOT FORTRAN IS THE FOURTH PROGRAM
              USES OPTPLOT DATA SET FROM OPTCALC
      THE SIZE OF THE DATA SETS VARY WITH THE SYSTEM
      ORDER, AND CAN USE ABOUT 20% OF THE USERS DISK SPACE.
      THEREFORE ENSURE THAT SUFFICIENT DISK SPACE IS
      AVAILABLE.
          IF DATA SET IS ALREADY AVAILABLE YOU MAY RUN ANY
          PROGRAM
        - ENTER  1 , 2 ,  3 ,  4     ANY OTHER INPUT
                                     RETURNS TO MENU
-ENDONE
&READ VARS &ANS
&IF .&ANS EQ .1 &GOTO -OPTSYS
&IF .&ANS EQ .2 &GOTO -OPTCALC1
&IF .&ANS EQ .3 &GOTO -OPGRAPH1
&IF .&ANS EQ .4 &EXIT &RC
&GOTO -START
-OPTSYS                    .
FILEDEF 8 DISK OPTPLOT DATA A1 (PERM
FILEDEF 9 DISK OPTMAT DATA A1 (PERM
FILEDEF 10 DISK OPTGROL DATA A1 (PERM
FILEDEF 01 DISK OPTGRNO DATA A1 (PERM
FILEDEF 04 DISK OPTGRCM DATA A1 (PERM
GLOBAL TXTLIB VFORTLIB IMSLDP  NONIMSL
&TYPE LOADING OPTSYS.... GENERAL STATE VARIABLE ANALYSIS
   PROGRAM
&TYPE....   OPTMAT DATA A1 ..... INPUT DATA SET ON RERUNS
OPTSYSX
CLRSCRN
&TYPE... DATA SETS  .. OPTMAT   AND  .. OPGRAPH  CREATED
CP SLEEP 5 SEC
```

```
&GOTO -START
-OPTCALC1
************************************************************
*                                                          *
*           CHECK FOR DATA IN THE FILE "OPTMAT DATA "      *
*                    BEFORE LOADING OPTCALC                *
*                                                          *
************************************************************
FINDSTAK OPTMAT DATA A1 C01 0 LIM002 ALL GROUP1
&READ VARS &A1 &A2
&IF .&A2 EQ .1 &GOTO -OPTCALC
&TYPE PROPER DATA FILE IS NOT AVAILABLE FOR OPTCALC
CP SLEEP 5 SEC
&GOTO -START
-OPTCALC
&TYPE.........OPTCALC.... TIME RESPONSE PROGRAM
FILEDEF 8 DISK OPTPLOT DATA A1 (PERM
FILEDEF 9 DISK OPTMAT DATA A1 (PERM
GLOBAL TXTLIB VFORTLIB IMSLDP  NONIMSL
OPTCALC
&TYPE    .. OPTPLOT DATA A1   CREATED
CP SLEEP 5 SEC
CLRSCRN
&BEGTYPE -ENDNINE
```

```
************************************************************
```

IF YOU ARE DISSATISFIED WITH THE RESULTS
THUS FAR AND WOULD LIKE TO EXIT TO CMS,

-TYPE 'Y' TO EXIT-

(ANY OTHER INPUT TO CONTINUE)

```
*************************************************************
-ENDNINE
&READ VARS &ANS
&IF .&ANS EQ .Y &GOTO -START
&TYPE PLOTS NEXT
CP SLEEP 4 SEC
GLOBAL TXTLIB DISLIBVS 92DISLIB 92INTLIB VFORTLIB GRFLIB
   NONIMSL CMSLIB
FILEDEF 8 DISK OPTPLOT DATA A1 (PERM
FILEDEF 11 DISK LBLANK TMP A3 (RECFM F LRECL 2400 BLKSIZE
   2400 BLKSIZE 2400 XTENT 600
FILEDEF 12 DISK ISSCCMAP MAPDTA * (RECFM F LRECL 400
   BLKSIZE 400
FILEDEF 13 DISK TABLET TMP A3 (RECFM VS LRECL 208 BLKSIZE
   208 XTENT 1000
FILEDEF 14 DISK LBLANK MAPDTA &LBMODE (RECFM VS LRECL 608
   BLKSIZE 608
FILEDEF 17 DISK DISSPLA SYSUT1 A3 (RECFM FB LRECL 2000
   BLOCK 2000 XTENT 500
FILEDEF 18 DISK DISSPLA METAFILE A4 (RECFM VBS LRECL 19065
   BLOCK 19069
OPTPLOT
&GOTO -META
-OPGRAPH1
*************************************************************
*                                                           *
*           CHECK FOR DATA IN THE OPTGRAPH DATA SETS "      *
*                    BEFORE LOADING OPGRAPH                 *
*                                                           *
*************************************************************
*************************************************************
RENAME OPTGROL DATA A1 OPTSYS DATA A1
&IF &RC NE 0 &GOTO -CPTNOISE
RENAME OPTSYS DATA A1 OPTGROL DATA A1
```

```
FINDSTAK OPTGROL DATA A1 C01 0 LIM002 ALL GROUP1
&READ VARS &A1 &A2 &A3 &A4 &A5
&IF .&A2 NE .0 &GOTO -SIXTEEN
-OPTNCISE
RENAME OPTGRNO DATA A1 OPTSYS DATA A1
&IF &RC NE 0 &GOTO -CPTCOMP
RENAME OPTSYS DATA A1 OPTGRNO DATA A1
FINDSTAK OPTGRNO DATA A1 C01 0 LIM002 ALL GROUP1
&READ VARS &A1 &A2 &A3 &A4 &A5
&IF .&A2 NE .0 &GOTO -SIXTEEN
-OPTCCMP
RENAME OPTGRCM DATA A1 OPTSYS DATA A1
&IF &RC NE 0 &GOTO -NCDATA
RENAME OPTSYS DATA A1 OPTGRCM DATA A1
FINDSTAK OPTGRCM DATA A1 C01 0 LIM002 ALL GROUP1
&READ VARS &A1 &A2 &A3 &A4 &A5
&IF .&A2 NE .0 &GOTO -SIXTEEN
-NODATA
&PRINT PROPER DATA FILE IS NOT AVAILABLE FOR OPGRAPH
CP SLEEP 5 SEC
&GOTO -START
-SIXTEEN
&TYPE  ...OPTGRAPH.... CLASSICAL ANALYSIS OF OPTSYS OUTPUT
SET LDRTELS 10
GLOBAL TXTLIB DISLIBVS 92DISLIB 92INTLIB VFORTLIB GRFLIB
   NONIMSL CMSLIB
SET LDRTBLS 10
FILEDEF 01 DISK OPTGRNO DATA A1 (PERM
FILEDEF 02 DISK OPGRAPH LISTING A1
FILEDEF 03 PRINTER (RECFM FA BLKSIZE 133 PERM
FILEDEF 04 DISK OPTGRCM DATA A1 (PERM
FILEDEF 06 TERM (RECFM FA BLKSIZE 133
FILEDEF 05 TERM (RECFM FA BLKSIZE 80
FILEDEF 10 DISK OPTGRCL DATA A1 (PERM
FILEDEF 11 DISK LBLANK TMP A3 (RECFM F LRECL 2400 BLKSIZE
```

```
   2400 XTENT 600
FILEDEF 12 DISK ISSCCMAP MAPDTA * (RECFM F LRECL 400
   BLKSIZE 400
FILEDEF 13 DISK TABLET TMP A3 (RECFM VS LRECL 208 BLKSIZE
   208 XTENT 1000
FILEDEF 14 DISK LBLANK MAPDTA &LBMODE (RECFM VS LRECL 608
   BLKSIZE 608
FILEDEF 17 DISK DISSPLA SYSUT1 A3 (RECFM FB LRECL 2000
   BLOCK 2000 XTENT 500
FILEDEF 18 DISK DISSPLA METAFILE A4 (RECFM VBS LRECL 19065
   BLOCK 19069
OPTGRAPH
-META
************************************************************
*                                                          *
*           CHECK FOR FILE "DISSPLA METAFILE A4" ON        *
*           THE USER'S DISK BEFORE GOING TO DISSPOP        *
*                                                          *
************************************************************
RENAME DISSPLA METAFILE A4 OPTSYS METAFILE A4
&IF &RETCODE NE 0 &GOTO -START
RENAME OPTSYS METAFILE A4 DISSPLA METAFILE A4
-EIGHT
CLRSCRN
&BEGTYPE -ENDTEN
```

```
************************************************************
```

DO YOU WANT A VRSTEC PLOTTER SMOOTH COPY OF THE
THE DISSPLA METAFILE THAT YOU JUST CREATED?

```
                    (Y OR N)
*************************************************************

-ENDTEN
&READ VARS &ANS
&IF .&ANS EQ .Y &GOTO -NINTH
&IF .&ANS EQ .N &GOTO -START
&GOTO -EIGHT
-NINTH
EXEC DISSPOP VRSTEC
CLRSCRN
&BEGTYPE -ENDTWELVE

*************************************************************

   YOUR GRAPH(S) CAN BE PICKED UP AT THE COMPUTER CENTER.

     THE GRAPH(S) WILL BE ADDRESSED TO "POP (USER ID)".

*************************************************************

-ENDTWELVE
CP SLEEP 5 SEC
&GOTO -START
```

APPENDIX B
OPTSYSX PROGRAM LISTING

This portion of the thesis contains the OPTSYSX FORTRAN program (88 pages).

```
C*************************************************************************OPT00010
C*************************************************************************OPT00020
C**********                                                     **********OPT00030
C*********                       OPTSYSX                         *********OPT00040
C********                  BY JOHN G. HODEN                       ********OPT00050
C********                                                         ********OPT00060
C********     THIS PROGRAM IS A COMPLETELY INTERACTIVE            ********OPT00070
C********     OPTIMAL SYSTEMS CONTROL DESIGN/SYNTHESIS            ********OPT00080
C********     PROGRAM CAPABLE OF HANDLING VERY LARGE (80X80)+     ********OPT00090
C********     MULTIVARIABLE SYSTEMS OF LINEAR EQUATIONS.          ********OPT00100
C********                                                         ********OPT00110
C**********          VERSION 1.8   11 MAR 1984                  **********OPT00120
C**********            MODIFIED BY AL DIEL                      **********OPT00130
C**********           MODIFIED BY M.H. LAPTAS                   **********OPT00140
C*************************************************************************OPT00150
C*************************************************************************OPT00160
      IMPLICIT REAL*8(A-H,C-Z)                                            OPT00170
C-----------------------------------------------------------------------OPT00180
      INTEGER IANS,IOL,IQ,IR,ISS,IM,ITF1,ITF2,ITF3,IFDFW,IE,IDEBUG,ISET,OPT00190
     1IPSD,IYU,INORM,NS,NC,NOB,NG,IREG,IDSTAB,IRET,NROW,NCOL,ISAF,ISAH,IOPT00200
     2SAG,IGAM,IRCMAT,ZERO,ONE,ITFX                                       OPT00210
C-----------------------------------------------------------------------OPT00220
C     INCREASED DIMENSIONS -- LARGE ORDER SYSTEM.                       OPT00230
C-----------------------------------------------------------------------OPT00240
C     DIMENSION ACL(98,98),B(3,3),BA(98,98),CI(98),CR(98),CQ(98,98),    OPT00250
C    *CWI(98),CWR(98),FBGC(3,98),FBGE(98,13),G(98,98),GM(98,98),        OPT00260
C    *PRO(98,98),RC(13,13),SC(98,98),WR(196),WI(196),W11(98,98),        OPT00270
C    *W21(98,98),X(196,196),GN(98,98),HO(13,98),D1(196),D2(196),        OPT00280
C    *RM(196,196),Q(1,1),GAM(98,1),WNORM(98,98),WNORMI(98,98),          OPT00290
C    *DESTAB(98),AA(98,98),BM(98,3),CM(13,98),D(13,3),DSTORE(98,98),    OPT00300
C    *JCF(196),RES(196),AY(98,98),BB(196),CC(196),CP(98),GW(196,1),     OPT00310
C    *GV(196,13),HY(13,196),HU(3,196),PRTT(16,16)                       OPT00320
C-----------------------------------------------------------------------OPT00330
C     STANDARD PROGRAM DIMENSIONS.                                      OPT00340
C-----------------------------------------------------------------------OPT00350
      DIMENSION ACL(32,32),B(32,32),BA(32,32),CI(32),CR(32),CQ(32,32),CWOPT00360
     1I(32),CWR(32),FBGC(32,32),FBGE(32,32),G(32,32),GM(32,32),PRO(32,32OPT00370
     2),RC(32,32),SC(32,32),WR(64),WI(64),W11(32,32),W21(32,32),X(64,64)OPT00380
     3,GN(32,32),HO(32,32),D1(64),D2(64),RM(64,64),Q(32,32),GAM(32,32),WOPT00390
     4NORM(32,32),WNORMI(32,32),DESTAB(32),AA(32,32),BM(32,32),CM(32,32)OPT00400
     5,D(32,32),DSTORE(32,32),JCF(64),RES(64),AY(32,32),BB(64),CC(64),CPOPT00410
     6(32),GW(64,64),GV(64,64),HY(64,64),HU(64,64),PRTT(16,16)          OPT00420
C-----------------------------------------------------------------------OPT00430
      EQUIVALENCE (W11(1,1),GW(1,1)), (W11(1,1),GV(1,1)), (W21(1,1),HY(1OPT00440
     1,1)), (W21(1,1),HU(1,1))                                           OPT00450
C-----------------------------------------------------------------------OPT00460
      COMMON /PROG/ IOL,IQ,IR,ISS,IM,ITF1,ITF2,ITF3,IFDFW,IE,IDSTAB,IDEBOPT00470
     1UG,ISET,IREG,IPSD,IYU,INORM                                        OPT00480
```

```
C-----------------------------------------------------------------------OPT00490
      DATA IY/'Y'/,IZ/'N'/                                               OPT00500
C-----------------------------------------------------------------------OPT00510
C  SUPPRESS INDIVIDUAL UNDERFLOW, OVERFLOW, DIVIDE CHECK, AND DECIMAL   =OPT00520
C  CONVERT ERROR MESSAGES; PROVIDE SUMMARY OF ERRORS ONLY.              =OPT00530
C-----------------------------------------------------------------------OPT00540
      CALL ERRSET (207,256,-1,1,1,209)                                   OPT00550
      CALL ERRSET (215,256,-1,1)                                         OPT00560
C-----------------------------------------------------------------------OPT00570
C  INITIALIZE SAVE FLAGS.                                               =OPT00580
C-----------------------------------------------------------------------OPT00590
      ISAF=0                                                             OPT00600
      ISAG=0                                                             OPT00610
      ISAH=0                                                             OPT00620
      IGAM=0                                                             OPT00630
      ISAA=0                                                             OPT00640
      ISAB=0                                                             OPT00650
      ISET=0                                                             OPT00660
C-------------------------------------SCRNA-----------------------------OPT00670
5     CALL FRTCMS ('CLRSCRN ')                                           OPT00680
      WRITE (5,885)                                                      OPT00690
      CALL RDINT (IANS)                                                  OPT00700
      IF(IANS.EQ.1) GO TO 20                                             OPT00710
      IF(IANS.EQ.2) GO TO 10                                             OPT00720
      GO TO 5                                                            OPT00730
C-------------------------------------SCRN1-----------------------------OPT00740
20    CALL FRTCMS ('CLRSCRN ')                                           OPT00750
      WRITE (5,890)                                                      OPT00760
      CALL RDCHAR (IANS)                                                 OPT00770
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 30                        OPT00780
      GO TO 40                                                           OPT00790
30    WRITE (5,880)                                                      OPT00800
      GO TO 20                                                           OPT00810
40    CONTINUE                                                           OPT00820
      IF (IANS.EQ.IZ) GO TO 560                                          OPT00830
C-------------------------------------SCRN2-----------------------------OPT00840
50    CALL FRTCMS ('CLRSCRN ')                                           OPT00850
      WRITE (5,900)                                                      OPT00860
      CALL RDCHAR (IANS)                                                 OPT00870
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 60                        OPT00880
      GO TO 70                                                           OPT00890
60    WRITE (5,880)                                                      OPT00900
      GO TO 50                                                           OPT00910
70    CONTINUE                                                           OPT00920
      IF (IANS.EQ.IZ) GO TO 560                                          OPT00930
C-------------------------------------ISET------------------------------OPT00940
80    CALL FRTCMS ('CLRSCRN ')                                           OPT00950
      WRITE (5,910)                                                      OPT00960
```

```
      CALL RDCHAR (IANS)                                                OPT00970
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 90                       OPT00980
      GO TO 100                                                         OPT00990
90    WRITE (5,880)                                                     OPT01000
      GO TO 80                                                          OPT01010
100   CONTINUE                                                          OPT01020
      IF (IANS.EQ.IY) ISET=1                                            OPT01030
C-------------------------------------------------------------------OPT01040
C  INITIALIZE SYSTEM FLAGS.                                          =OPT01050
C-------------------------------------------------------------------OPT01060
10    CONTINUE                                                          OPT01070
      IRET=0                                                            OPT01080
      IOL=0                                                             OPT01090
      IQ=0                                                              OPT01100
      IR=0                                                              OPT01110
      ISS=0                                                             OPT01120
      IM=0                                                              OPT01130
      ITF1=0                                                            OPT01140
      ITF2=0                                                            OPT01150
      ITF3=0                                                            OPT01160
      IFDFW=0                                                           OPT01170
      IE=0                                                              OPT01180
      IDSTAB=0                                                          OPT01190
      IDEBUG=0                                                          OPT01200
      IPSD=0                                                            OPT01210
      IYU=0                                                             OPT01220
      INCRM=0                                                           OPT01230
      IREG=0                                                            OPT01240
      NS=0                                                              OPT01250
      NC=0                                                              OPT01260
      NOB=0                                                             OPT01270
      NG=0                                                              OPT01280
      IRDMAT=0                                                          OPT01290
C-----------------------------------------------ICL-------------------OPT01300
      CALL FRTCMS ('CLRSCRN ')                                          OPT01310
      WRITE (5,570)                                                     OPT01320
      CALL RDINT (IANS)                                                 OPT01330
      ICL=IANS-1                                                        OPT01340
      IF (IOL.EQ.2) GO TO 350                                           OPT01350
      IF (IOL.EQ.3) GO TO 200                                           OPT01360
C-----------------------------------------------IQ--------------------OPT01370
      CALL FRTCMS ('CLRSCRN ')                                          OPT01380
110   WRITE (5,580)                                                     OPT01390
      CALL RDCHAR (IANS)                                                OPT01400
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 120                      OPT01410
      GO TO 130                                                         OPT01420
120   WRITE (5,880)                                                     OPT01430
      GO TO 110                                                         OPT01440
```

```
130   CONTINUE                                                          OPT01450
      IF (IANS.EQ.IY) IQ=1                                              OPT01460
      IF (IANS.EQ.IZ) IQ=0                                              OPT01470
C-----------------------------------------------IR----------------------OPT01480
      CALL FRTCMS ('CLRSCRN ')                                          OPT01490
      WRITE (5,590)                                                     OPT01500
      CALL RDINT (IANS)                                                 OPT01510
      IR=IANS-1                                                         OPT01520
C-----------------------------------------------ISS---------------------OPT01530
      CALL FRTCMS ('CLRSCRN ')                                          OPT01540
140   WRITE (5,600)                                                     OPT01550
      CALL RDCHAR (IANS)                                                OPT01560
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 150                      OPT01570
      GO TO 160                                                         OPT01580
150   WRITE (5,880)                                                     OPT01590
      GO TO 140                                                         OPT01600
160   CONTINUE                                                          OPT01610
      IF (IANS.EQ.IY) ISS=1                                             OPT01620
      IF (IANS.EQ.IZ) ISS=0                                             OPT01630
C-----------------------------------------------IM----------------------OPT01640
170   WRITE (5,610)                                                     OPT01650
      CALL RDCHAR (IANS)                                                OPT01660
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 180                      OPT01670
      GO TO 190                                                         OPT01680
180   WRITE (5,880)                                                     OPT01690
      GO TO 170                                                         OPT01700
190   CONTINUE                                                          OPT01710
      IF (IANS.EQ.IY) IM=1                                              OPT01720
      IF (IANS.EQ.IZ) IM=0                                              OPT01730
200   CONTINUE                                                          OPT01740
      IF (IOL.EQ.3) IM=1                                                OPT01750
C-----------------------------------------------IFDFW-------------------OPT01760
      CALL FRTCMS ('CLRSCRN ')                                          OPT01770
210   WRITE (5,650)                                                     OPT01780
      CALL RDCHAR (IANS)                                                OPT01790
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 220                      OPT01800
      GO TO 230                                                         OPT01810
220   WRITE (5,880)                                                     OPT01820
      GO TO 210                                                         OPT01830
230   CONTINUE                                                          OPT01840
      IF (IANS.EQ.IY) IFDFW=1                                           OPT01850
      IF (IANS.EQ.IZ) IFDFW=0                                           OPT01860
      IF (IOL.EQ.3) GO TO 350                                           OPT01870
C-----------------------------------------------IDSTAB-----------------OPT01880
      CALL FRTCMS ('CLRSCRN ')                                          OPT01890
240   WRITE (5,670)                                                     OPT01900
      CALL RDCHAR (IANS)                                                OPT01910
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 250                      OPT01920
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```
      GO TO 260                                                          OPT01930
250   WRITE (5,88C)                                                      OPT01940
      GO TO 240                                                          OPT01950
260   CONTINUE                                                           OPT01960
      IF (IANS.EQ.IY) IDSTAB=1                                           OPT01970
      IF (IANS.EQ.IZ) IDSTAB=0                                           OPT01980
C-----------------------------------------IDEBUG-----------------OPT01990
270   WRITE (5,68C)                                                      OPT02000
      CALL RDCHAR (IANS)                                                 OPT02010
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 280                       OPT02020
      GO TO 290                                                          OPT02030
280   WRITE (5,88C)                                                      OPT02040
      GO TO 270                                                          OPT02050
290   CONTINUE                                                           OPT02060
      IF (IANS.EQ.IY) IDEBUG=1                                           OPT02070
      IF (IANS.EQ.IZ) IDEBUG=0                                           OPT02080
300   CONTINUE                                                           OPT02090
C-----------------------------------------IREG-------------------OPT02100
      CALL FRTCMS ('CLRSCRN ')                                           OPT02110
320   WRITE (5,71C)                                                      OPT02120
      CALL RDCHAR (IANS)                                                 OPT02130
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 330                       OPT02140
      GO TO 340                                                          OPT02150
330   WRITE (5,88C)                                                      OPT02160
      GO TO 320                                                          OPT02170
340   CONTINUE                                                           OPT02180
      IF (IANS.EQ.IY) IREG=1                                             OPT02190
      IF (IANS.EQ.IZ) IREG=0                                             OPT02200
350   CALL RDMATF(NS,NC,NCB,NG,ISAF,ISAG,ISAH,IGAM,ISAA,ISAB,IRDMAT)     OPT02210
      IF ((ISAF.EQ.1).AND.(IRDMAT.EQ.1)) GO TO 352                       OPT02220
C-----------------------------------------NS---------------------OPT02230
      CALL FRTCMS ('CLRSCRN ')                                           OPT02240
      WRITE (5,72C)                                                      OPT02250
      CALL RDREAL (ANSR)                                                 OPT02260
      NS=IDINT(ANSR)                                                     OPT02270
352   IF (IOL.EQ.2) GO TO 360                                            OPT02280
      IF ((ISAG.EQ.1).AND.(IRDMAT.EQ.1)) GO TO 354                       OPT02290
C-----------------------------------------NC---------------------OPT02300
      WRITE (5,73C)                                                      OPT02310
      CALL RDREAL (ANSR)                                                 OPT02320
      NC=IDINT(ANSR)                                                     OPT02330
354   IF ((ISAH.EQ.1).AND.(IRDMAT.EQ.1)) GO TO 356                       OPT02340
C-----------------------------------------NCB--------------------OPT02350
      WRITE (5,74C)                                                      OPT02360
      CALL RDREAL (ANSR)                                                 OPT02370
      NCB=IDINT(ANSR)                                                    OPT02380
356   IF ((IGAM.EQ.1).AND.(IRDMAT.EQ.1)) GO TO 360                       OPT02390
C-----------------------------------------NG---------------------OPT02400
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      WRITE (5,750)                                                     OPT02410
      CALL RDREAL (ANSR)                                                OPT02420
      NG=IDINT(ANSR)                                                    OPT02430
360   CONTINUE                                                          OPT02440
      IF (IOL.EQ.2) GO TO 364                                           OPT02450
      IF (IOL.EQ.3) GO TO 310                                           OPT02460
C-----------------------------------------------IPSD------------------OPT02470
      IF(IREG.NE.C.OR.NC.EC.0) GO TO 310                                OPT02480
      CALL FRTCMS ('CLRSCRN ')                                          OPT02490
      WRITE (5,690)                                                     OPT02500
      CALL RDINT (IANS)                                                 OPT02510
      IPSD=IANS                                                         OPT02520
      IF (IPSD.EC.3) IPSD=0                                             OPT02530
      IF (IPSD.EC.0) GO TO 310                                          OPT02540
C-----------------------------------------------IYU-------------------OPT02550
      CALL FRTCMS ('CLRSCRN ')                                          OPT02560
      WRITE (5,700)                                                     OPT02570
      CALL RDINT (IANS)                                                 OPT02580
      IYU=IANS-1                                                        OPT02590
C-----------------------------------------------INCRM-----------------OPT02600
      CALL FRTCMS ('CLRSCRN ')                                          OPT02610
      WRITE (5,820)                                                     OPT02620
      CALL RDREAL (ANSR)                                                OPT02630
      INORM=IDINT(ANSR)                                                 OPT02640
310   CONTINUE                                                          OPT02650
C-----------------------------------------------ITF1------------------OPT02660
      CALL FRTCMS ('CLRSCRN ')                                          OPT02670
      WRITE (5,620)                                                     OPT02680
      CALL RDINT (IANS)                                                 OPT02690
      ITF1=IANS-1                                                       OPT02700
      IF (IOL.EQ.3) GO TO 362                                           OPT02710
C-----------------------------------------------ITF2------------------OPT02720
      IF(IREG.NE.1) GO TO 315                                           OPT02730
      CALL FRTCMS ('CLRSCRN ')                                          OPT02740
      WRITE (5,630)                                                     OPT02750
      CALL RDINT (IANS)                                                 OPT02760
      ITF2=IANS-1                                                       OPT02770
C-----------------------------------------------ITF3------------------OPT02780
315   IF (IREG.NE.0 .OR. (NC.EQ.0 .CR. NG.EQ.0)) GO TO 362              OPT02790
      CALL FRTCMS ('CLRSCRN ')                                          OPT02800
      WRITE (5,640)                                                     OPT02810
      CALL RDINT (IANS)                                                 OPT02820
      ITF3=IANS-1                                                       OPT02830
C-----------------------------------------------IE--------------------OPT02840
362   CONTINUE                                                          OPT02850
      IF((ITF1+ITF2+ITF3).EQ.0) GO TO 364                               OPT02860
      CALL FRTCMS ('CLRSCRN ')                                          OPT02870
      WRITE (5,660)                                                     OPT02880
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      CALL RDREAL (ANSR)                                                OPT02890
      IE=IDINT(ANSR)                                                    OPT02900
C-----------------------------------------------FLAG SETTINGS----------OPT02910
364   CONTINUE                                                          OPT02920
      CALL FRTCMS ('CLRSCRN ')                                          OPT02930
      WRITE (6,760)                                                     OPT02940
      WRITE (6,770)                                                     OPT02950
      WRITE (6,780) IOL,IQ,IR,ISS,IM,ITF1,ITF2,ITF3,IFDFW,IE,IDEBUG,ISETOPT02960
     1,IDSTAB                                                           OPT02970
      WRITE (6,790)                                                     OPT02980
      WRITE (6,800) IPSD,IYU,INORM,IREG,NS,NC,NOB,NG                    OPT02990
      WRITE (6,810) NS,NC,NOB,NG                                        OPT03000
C-----------------------------------------------CPTGRAPH DATA FILES ---OPT03010
      ZERO = 0                                                          OPT03020
      ONE = 1                                                           OPT03030
      REWIND 10                                                         OPT03040
      ITFX = 1                                                          OPT03050
      WRITE (10,1000) ZERO,ONE,NS,NC,NOB,IE,ITFX                        OPT03060
      REWIND 1                                                          OPT03070
      ITFX = 2                                                          OPT03080
      WRITE (1,1000) ZERO,ONE,NS,NG,NOB,IE,ITFX                         OPT03090
      REWIND 4                                                          OPT03100
      ITFX = 3                                                          OPT03110
      WRITE (4,1000) ZERO,ONE,NS,NOB,NC,IE,ITFX                         OPT03120
C-----------------------------------------------BEGIN CALCULATIONS-----OPT03130
      N2=2*NS                                                           OPT03140
      CALL INNER (NS,NC,NOB,NG,N2,ACL,B,BA,CI,CR,CC,CWI,CWR,D,FBGC,FBGE,OPT03150
     1G,GAM,GM,GN,HC,D1,D2,PRO,RM,RC,Q,SC,WR,WI,W11,W21,X,WNORM,WNORMI,DOPT03160
     2ESTAB,AA,BM,CM,JCF,RES,AY,BB,CC,CP,GW,GV,HY,HU,DSTORE,ISAF,ISAH,ISOPT03170
     3AG,IGAM,IRET,PRTT,NROW,NCOL,IRDMAT,ISAA,ISAB)                     OPT03180
C-----------------------------------------------CPTGROL DATA----------OPT03190
      IF((ITF1.EQ.1).OR.(ITF1.EQ.2)) GO TO 396                          OPT03200
      END FILE 10                                                       OPT03210
      REWIND 10                                                         OPT03220
      ITFX = 1                                                          OPT03230
      WRITE (10,1000) ZERO,ZERO,ZERO,ZERO,ZERO,ZERO,ITFX                OPT03240
C-----------------------------------------------CPTGRNO DATA----------OPT03250
396   IF((ITF2.EQ.1).OR.(ITF2.EQ.2)) GO TO 397                          OPT03260
      END FILE 1                                                        OPT03270
      REWIND 1                                                          OPT03280
      ITFX = 2                                                          OPT03290
      WRITE (1,1000) ZERO,ZERO,ZERO,ZERO,ZERO,ZERO,ITFX                 OPT03300
C-----------------------------------------------OPTGRCM DATA----------OPT03310
397   IF((ITF1.EQ.3).OR.(ITF3.EQ.2)) GO TO 398                          OPT03320
      END FILE 4                                                        OPT03330
      REWIND 4                                                          OPT03340
      ITFX = 3                                                          OPT03350
      WRITE (4,1000) ZERO,ZERO,ZERO,ZERO,ZERO,ZERO,ITFX                 OPT03360
```

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C-----------------------------------------------------------------------OPT03370
398   IF(IRET.EQ.1) GO TO 370                                            OPT03380
      CALL WRTMAT(BA,G,HO,GAM,FBGC,FBGE,AY,B,NS,NC,NOB,NG)               OPT03390
C-------------------------------------------------IRET------------------OPT03400
370   WRITE (5,830)                                                      OPT03410
      CALL RDCHAR (IANS)                                                 OPT03420
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 380                       OPT03430
      GO TO 390                                                          OPT03440
380   WRITE (5,880)                                                      OPT03450
      GO TO 370                                                          OPT03460
390   CONTINUE                                                           OPT03470
C-----------------------------------------RESET OPGRAPH DATA FILE        OPT03480
      IF(IANS.EQ.IZ) GO TO 395                                           OPT03490
      END FILE 10                                                        OPT03500
      REWIND 10                                                          OPT03510
      END FILE 1                                                         OPT03520
      REWIND 1                                                           OPT03530
      END FILE 4                                                         OPT03540
      REWIND 4                                                           OPT03550
C-----------------------------------------------------------------------OPT03560
395   IF (IANS.EQ.IY) GO TO 400                                          OPT03570
      IF (IANS.EQ.IZ) GO TO 560                                          OPT03580
C-------------------------------------------------ISAF------------------OPT03590
400   CONTINUE                                                           OPT03600
      IF (IRET.EQ.1) GO TO 10                                            OPT03610
      IF (ISET.EQ.1) GO TO 10                                            OPT03620
      CALL FRTCMS ('CLRSCRN ')                                           OPT03630
410   WRITE (5,840)                                                      OPT03640
      CALL RDCHAR (IANS)                                                 OPT03650
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 420                       OPT03660
      GO TO 430                                                          OPT03670
420   WRITE (5,880)                                                      OPT03680
      GO TO 410                                                          OPT03690
430   CONTINUE                                                           OPT03700
      IF (IANS.EQ.IY) ISAF=1                                             OPT03710
      IF (IANS.EQ.IZ) ISAF=0                                             OPT03720
C-------------------------------------------------ISAH------------------OPT03730
      IF (NOB.EQ.0) GO TO 470                                            OPT03740
      CALL FRTCMS ('CLRSCRN ')                                           OPT03750
440   WRITE (5,850)                                                      OPT03760
      CALL RDCHAR (IANS)                                                 OPT03770
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 450                       OPT03780
      GO TO 460                                                          OPT03790
450   WRITE (5,880)                                                      OPT03800
      GO TO 440                                                          OPT03810
460   CONTINUE                                                           OPT03820
      IF (IANS.EQ.IY) ISAH=1                                             OPT03830
      IF (IANS.EQ.IZ) ISAH=0                                             OPT03840
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470   CONTINUE                                                          OPT03850
C-------------------------------------------------ISAG-----------------OPT03860
      IF (NC.EQ.C) GO TO 510                                            OPT03870
      CALL FRTCMS ('CLRSCRN ')                                          OPT03880
480   WRITE (5,86C)                                                     OPT03890
      CALL RDCHAR (IANS)                                                OPT03900
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 490                      OPT03910
      GO TO 500                                                         OPT03920
490   WRITE (5,88C)                                                     OPT03930
      GO TO 480                                                         OPT03940
500   CONTINUE                                                          OPT03950
      IF (IANS.EC.IY) ISAG=1                                            OPT03960
      IF (IANS.EC.IZ) ISAG=0                                            OPT03970
510   CONTINUE                                                          OPT03980
C-------------------------------------------------IGAM-----------------OPT03990
      IF (NG.EQ.C) GO TO 550                                            OPT04000
      CALL FRTCMS ('CLRSCRN ')                                          OPT04010
520   WRITE (5,87C)                                                     OPT04020
      CALL RDCHAR (IANS)                                                OPT04030
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 530                      OPT04040
      GO TO 540                                                         OPT04050
530   WRITE (5,88C)                                                     OPT04060
      GC TO 520                                                         OPT04070
540   CONTINUE                                                          OPT04080
      IF (IANS.EC.IY) IGAM=1                                            OPT04090
      IF (IANS.EC.IZ) IGAM=0                                            OPT04100
550   CONTINUE                                                          OPT04110
C-------------------------------------------------ISAA-----------------OPT04120
      CALL FRTCMS ('CLRSCRN ')                                          OPT04130
551   WRITE (5,872)                                                     OPT04140
      CALL RDCHAR (IANS)                                                OPT04150
      IF ((IANS.EC.IY).OR.(IANS.EQ.IZ)) GO TO 553                       OPT04160
      WRITE (5,88C)                                                     OPT04170
      GO TO 551                                                         OPT04180
553   CONTINUE                                                          OPT04190
      IF (IANS.EC.IY) ISAA=1                                            OPT04200
      IF (IANS.EC.IZ) ISAA=0                                            OPT04210
C-------------------------------------------------ISAB-----------------OPT04220
      CALL FRTCMS ('CLRSCRN ')                                          OPT04230
555   WRITE (5,874)                                                     OPT04240
      CALL RDCHAR (IANS)                                                OPT04250
      IF ((IANS.EC.IY).OR.(IANS.EQ.IZ)) GO TO 557                       OPT04260
      WRITE (5,88C)                                                     OPT04270
      GC TO 555                                                         OPT04280
557   CONTINUE                                                          OPT04290
      IF (IANS.EC.IY) ISAB=1                                            OPT04300
      IF (IANS.EC.IZ) ISAB=0                                            OPT04310
      GO TO 10                                                          OPT04320
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C-----------------------------------------TERMINATE----------OPT04330
560   WRITE (5,920)                                           OPT04340
      STOP                                                    OPT04350
C-------------------------------------------------------------OPT04360
885   FORMAT (5X,33HIN CASE OF PROBLEMS CALL EXT 2826,///,10X,42H1  DEFIOPT04370
     1NES MATRIX EQUATIONS USED IN OPTSYS,/,15X,32HAND ALTERNATE DATA INOPT04380
     2PUT METHODS,//,10X,26H2  START INTERACTIVE INPUT,///,15X,13HENTER OPT04390
     3 1 OR 2,///,5X,59HNORMALLY TWO SUCCESSIVE NULL ENTERS TERMINATES TOPT04400
     4HE PROGRAM.)                                            OPT04410
890   FORMAT (5X,59HOPTSYSX IS A COMPLETELY INTERACTIVE OPTIMAL SYSTEMS OPT04420
     1CONTROL,/,8X,55HPROGRAM.  IT WILL SOLVE NUMEROUS CONTROL PROBLEMS OOPT04430
     2N THE,/,8X,45HFOLLOWING TYPES OF SYSTEMS CONTROL EQUATIONS:,//,15XOPT04440
     3,35HXDOT =  F&*X +  G&*U +  GAM&*(W+WO),//,20X,22HMEASUREMENT EQUAOPT04450
     4TION--,//,15X,21HZ =  H&*X +  D&*U + V,//,20X,29HREGULATOR PERFORMOPT04460
     5ANCE INDEX--,//,15X,42HJ = 1/2 * INTEGRAL (Y9* A&*Y + U9* B&*U)DT,OPT04470
     6//,20X,32HSTATE FEEDBACK GAIN DEFINITION--,//,25X,1CHU = - C&*X,//OPT04480
     7,15X,45HDO YOU WISH TO CONTINUE?  TYPE "YES" OR "NO".)  OPT04490
900   FORMAT (25X,14H--DATA ENTRY--,//,5X,49HALTHOUGH OPTSYSX IS SPECIFIOPT04500
     1CALLY DESIGNED TO READ,/,5X,48HALL MATRIX DATA INTERACTIVELY, SEVEOPT04510
     2RAL ALTERNATE,/,5X,31HMETHODS ARE AVAILABLE TO USERS:,//,10X,43HMEOPT04520
     3THOD 1--THE "F","G", AND "GAMMA" MATRICES,/,13X,37HMAY BE READ FROOPT04530
     4M SEPARATE DATA FILES.,//,10X,50HMETHOD 2--THE "F","G", AND "GAMMAOPT04540
     5" MATRICES MAY BE,/,13X,45HEXPLICITLY DEFINED WITHIN SUBROUTINE "SOPT04550
     6ETUP".,//,10X,52H NOTE: IN EITHER CASE, THE USER SHOULD OBTAIN A COPT04560
     7OPY,/,17X,34HOF THE PROGRAM LISTING AND EXAMINE,/,17X,39HTHE EXAMPOPT04570
     8LES CONTAINED IN S/R "SETUP".&,//,10X,45HDO YOU WISH TO CONTINUE? OPT04580
     9 TYPE "YES" OR "NO".)                                   OPT04590
910   FORMAT (//,5X,46HDO YOU WISH TO INPUT THE "F", "G", AND "GAMMA",/,OPT04600
     110X,40HMATRICES FROM SUBROUTINE "SETUP" IAW THE,/,10X,40HMETHOD DEOPT04610
     2SCRIBED ON THE PREVIOUS SCREEN?,//,15X,19HTYPE "YES" OR "NO".)   OPT04620
970   FORMAT (25X,24HGENERAL OPTSYSX OPTIONS:,//,10X,35HOPTION 1 -- SYSTOPT04630
     1EM ANALYSIS WITHOUT,/,22X,35HOPEN-LOOP EIGENSYSTEM CALCULATIONS.,/OPT04640
     2/,10X,42HOPTION 2 -- SYSTEM ANALYSIS WITH OPEN-LOOP,/,22X,25HEIGENOPT04650
     3SYSTEM CALCULATIONS.,//,10X,39HOPTION 3 -- OPEN-LOOP EIGENSYSTEM FOPT04660
     4OUND,/,22X,23HAND PROGRAM TERMINATES.,/,22X,39H "F"-MATRIX ENTRY FOPT04670
     5OLLOWS IMMEDIATELY.&,//,10X,48HOPTION 4 -- MODAL DISTRIBUTION MATROPT04680
     6ICES COMPUTED,/,22X,37HWITHOUT FILTER OR REGULATOR SYNTHESIS,/,22XOPT04690
     7,25HOR STEADY-STATE ANALYSIS.,//,15X,30HSELECT AN OPTION: 1,2,3, OOPT04700
     8R 4.)                                                   OPT04710
980   FORMAT (//,5X,46HDO YOU DESIRE RMS VALUES OF STATE AND CONTROL?,//OPT04720
     1,10X,19HTYPE "YES" OR "NO".)                            OPT04730
990   FORMAT (/,20X,30HOPTSYSX LQR/CLASSICAL OPTIONS:,//,10X,43HOPTION 1OPT04740
     1 -- OPTIMAL FILTER AND/OR REGULATOR,/,22X,37HSYNTHESIS WITH NO EXTOPT04750
     2ERNAL "C" OR "K",/,22X,13HMATRIX INPUT.,//,10X,43HOPTION 2 -- OPTIOPT04760
     3MAL FILTER AND/OR REGULATOR,/,22X,27HSYNTHESIS WITH EXTERNAL "C",/OPT04770
     4,22X,13HMATRIX INPUT.,//,10X,43HOPTION 3 -- OPTIMAL FILTER AND/OR OPT04780
     5REGULATOR,/,22X,27HSYNTHESIS WITH EXTERNAL "K",/,22X,13HMATRIX INPOPT04790
     6UT.,//,10X,  'OPTION 4 -- SYSTEM ANALYSIS'                ,/,22X,  OPT04800
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     7          'WITH EXTERNAL "C" AND "K" MATRIX INPUT.',//,10X                OPT04810
     8,32HSELECT AN OPTION: 1, 2, 3, OR 4.)                                     OPT04820
600   FORMAT (//,5X,50HDO YOU WISH TO DETERMINE THE STEADY-STATE RESPONSOPT04830
     1E,/,8X,27HFOR A CONSTANT DISTURBANCE?,//,10X,19HTYPE "YES" OR "NO"OPT04840
     2.)                                                                        OPT04850
610   FORMAT (5X,47HDO YOU WISH TO DETERMINE THE MODAL DISTRIBUTION,/,8XOPT04860
     1,18HAND GAIN MATRICES?,//,10X,19HTYPE "YES" OR "NO".)                     OPT04870
620   FORMAT (//,5X,36HOPEN-LOOP TRANSFER FUNCTION OPTIONS:,//,10X,52HOPOPT04880
     1TION 1 -- NO OPEN-LOOP TRANSFER FUNCTIONS COMPUTED.,//,10X,48HOPTIOPT04890
     2ON 2 -- POLES, RESIDUES, AND ZEROS COMPUTED.,//,10X,42HOPTION 3 --OPT04900
     3 ONLY POLES AND ZEROS COMPUTED.,//,10X,45HOPTION 4 -- ONLY POLES AOPT04910
     4ND RESIDUES COMPUTED.,//,10X,32HSELECT AN OPTION: 1, 2, 3, OR 4.,/OPT04920
     5//,8X,32HIF ANALYSIS CAUSES MODAL OUTPUT,//,5X,61HPOLES AND ZEROSOPT04930
     6 MUST BE SELECTED IF YOU WISH TO USE OPTGRAPH.)                           OPT04940
630   FORMAT (//,5X,32HNOISE TRANSFER FUNCTION OPTIONS:,//,10X,49HOPTIONOPT04950
     1 1 -- NO NOISE TRANSFER FUNCTIONS COMPUTED.,//,10X,48HOPTION 2 -- OPT04960
     2POLES, RESIDUES, AND ZEROS COMPUTED.,//,10X,42HOPTION 3 -- ONLY POOPT04970
     3LES AND ZEROS COMPUTED.,//,10X,45HOPTION 4 -- ONLY POLES AND RESIDOPT04980
     4LES COMPUTED.,//,10X,32HSELECT AN OPTION: 1, 2, 3, OR 4.)                 OPT04990
640   FORMAT (//,5X,38HCOMPENSATOR TRANSFER FUNCTION OPTIONS:,//,10X,49HOPT05000
     1OPTION 1 -- NO COMP. TRANSFER FUNCTIONS COMPUTED.,//,10X,48HOPTIONOPT05010
     2 2 -- POLES, RESIDUES, AND ZEROS COMPUTED.,//,10X,42HOPTION 3 -- OOPT05020
     3NLY POLES AND ZEROS COMPUTED.,//,10X,45HOPTION 4 -- ONLY POLES ANDOPT05030
     4 RESIDUES COMPUTED.,//,15X,45H NOTE: A COMPENSATOR TRANSFER FUNCTIOPT05040
     5ON CAN BE,/,22X,33HCOMPUTED ONLY IF BOTH A REGULATOR,/,22X,26HAND OPT05050
     6FILTER ARE SYNTHESIZED,/,22X,14HAND/OR INPUT.&,//,10X,32HSELECT ANOPT05060
     7 OPTION: 1, 2, 3, OR 4.)                                                  OPT05070
650   FORMAT (//,5X,39HWILL A FEED-FORWARD DISTRIBUTION MATRIX,/,5X,25H OPT05080
     1"D" - MATRIX& BE INPUT ?,//,15X,19HTYPE "YES" OR "NO".)                   OPT05090
660   FORMAT (/,5X,63H THIS OPTION DETERMINES THE CRITERIA FOR DECIDING OPT05100
     1WHEN A MARKOV,/,8X,58HPARAMETER IS ZERO-THE MARKOV PARAMETER INDICOPT05110
     2ATES THE ORDER,/,8X,54HOF THE NUMERATOR POLYNOMIAL OF EACH TRANSFEOPT05120
     3R FUNCTION.,//,8X,52HALL "N" ZEROS OF THIS POLYNOMIAL ARE PRINTED OPT05130
     4OUT AND,/,8X,52HTHIS TEST TELLS HOW MANY EXTRA ROOTS EXIST AT Z = OPT05140
     50.,/,8X,41HLESS THAN 10.0** -IE& IS CONSIDERED ZERO.,//,8X,47H THEOPT05150
     6 DEFAULT VALUE OF THIS PARAMETER  IE& IS 6.,/,8X,28HIN OTHER WORDSOPT05160
     7,ESP = 1.0E-6.,//,10X,66HIF YOU DESIRE A DIFFERENT MARKOV CRITERIAOPT05170
     8, TYPE THE INTEGER VALUE.,//,10X,48HIF YOU DESIRE THE DEFAULT VALUOPT05180
     9E, TYPE "0"  ZERO&)                                                       OPT05190
670   FORMAT (//,5X,61HDO YOU DESIRE TO SYNTHESIZE A STABLE FILTER  OR ROPT05200
     1EGULATOR& BY,/,8X,34HDESTABILIZING THE ORIGINAL SYSTEM?,//,12X,52HOPT05210
     2 NOTE:WORKS FOR FILTER OR REGULATOR BUT NOT FOR BOTH,/,20X,17HIN TOPT05220
     3HE SAME RUN.&,//,10X,19HTYPE "YES" OR "NO".)                              OPT05230
680   FORMAT (5X,53HDO YOU DESIRE TO PRINT THE EULER-LAGRANGE EIGENSYSTEOPT05240
     1M,/,8X,50HPRIOR TO DECOMPOSITION  FOR CHECKING THE PROGRAM&?,//,10OPT05250
     2X,19HTYPE "YES" OR "NO".)                                                 OPT05260
690   FORMAT (//,5X,39HPOWER SPECTRAL DENSITY  PSD& OPTION 1 :,//,10X,53OPT05270
     1HOPTION 1 -- COMPUTE THE PSD OF THE OUTPUTS AND/OR THE,/,22X,48HCOOPT05280
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     2NTROLS OF THE CONTROLLED SYSTEM WHEN FORCED BY,/,22X,45HPROCESS ANOPT05290
     3D MEASUREMENT NOISE.   NOTE: BOTH A,/,22X,46HREGULATOR AND A FILTEOPT05300
     4R MUST BE RESIDENT IN THE,/,22X,28HPROGRAM TO USE THIS OPTION.&,//OPT05310
     5,10X,53HOPTION 2 -- SAME AS OPTION 1 ABOVE BUT ONLY PRINT THE,/,22OPT05320
     6X,34HRESIDUES OF EACH TRANSFER FUNCTION,/,22X,28HUSED IN THE PSD COPT05330
     7CMPUTATION.,//,10X,24HOPTION 3 -- NOT DESIRED.,///,10X,29HSELECT AOPT05340
     8N OPTION: 1, 2, OR 3.)                                            OPT05350
700   FORMAT (//,5X,39HPOWER SPECTRAL DENSITY  PSD& OPTION 2 :,//,10X,35OPT05360
     1HOPTION 1 -- PSD OUTPUT NOT DESIRED.,//,10X,38HOPTION 2 -- COMPUTEOPT05370
     2 ONLY OUTPUT PSD/S.,//,10X,39HOPTION 3 -- COMPUTE ONLY CONTROL PSDOPT05380
     3/S.,//,10X,50HOPTION 4 -- COMPUTE BOTH OUTPUT AND CONTROL PSD/S.,/OPT05390
     4/,15X,32HSELECT AN OPTION: 1, 2, 3, OR 4.)                        OPT05400
710   FORMAT (//,5X,39HDO YOU DESIRE REGULATOR SYNTHESIS ONLY?,//,10X,19OPT05410
     1HTYPE "YES" OR "NO".,//)                                          OPT05420
720   FORMAT (/,5X,47HENTER THE # OF STATES  NS& OF THE SYSTEM MATRIX,/,OPT05430
     15X,13H "F"-MATRIX&.)                                              OPT05440
730   FORMAT (/,5X,56HENTER THE # OF CONTROLS  NC& OF THE CONTROL SYSTEMOPT05450
     1 MODEL,/,5X,13H "G"-MATRIX&.)                                     OPT05460
740   FORMAT (/,5X,54HENTER THE # OF MEASUREMENTS OR OBSERVATIONS  NO& OOPT05470
     1FTHE,/,5X,13H "H"-MATRIX&.)                                       OPT05480
750   FORMAT (/,5X,48HENTER THE # OF PROCESS NOISE SOURCES  NG& OF THE,/OPT05490
     1,5X,17H "GAMMA"-MATRIX&.)                                         OPT05500
760   FORMAT (5X,52HFLAG/PARAMETER SETTINGS FOR THIS RUN ARE AS FOLLOWS:OPT05510
     1,/)                                                               OPT05520
770   FORMAT (1X,3HIOL,2X,2HIQ,2X,2HIR,2X,3HISS,2X,2HIM,2X,4HITF1,2X,4HIOPT05530
     1TF2,2X,4HITF3,2X,5HIFDFW,2X,2HIE,2X,6HIDEBUG,2X,4HISET,2X,6HIDSTABOPT05540
     2,/)                                                               OPT05550
780   FORMAT (1X,I2,3X,I2,3X,I2,2X,I2,3X,I2,3X,I2,4X,I2,4X,I2,4X,I2,4X,IOPT05560
     12,3X,I2,6X,I2,5X,I2,/)                                            OPT05570
790   FORMAT (1X,4HIPSD,2X,3HIYU,2X,5HINORM,2X,4HIREG,2X,2HNS,2X,2HNC,2XOPT05580
     1,3HNOB,2X,2HNG,/)                                                 OPT05590
800   FORMAT (2X,I2,3X,I2,4X,I2,5X,I2,3X,I2,2X,I2,3X,I2,2X,I2,//)       OPT05600
810   FORMAT (2X,17HORDER OF SYSTEM =,I3,//,2X,20HNUMBER OF CONTROLS =,IOPT05610
     13,//,2X,24HNUMBER OF OBSERVATIONS =,I3,//,2X,33HNUMBER OF PROCESS OPT05620
     2NOISE SOURCES =,I3,////)                                          OPT05630
820   FORMAT (5X,53HDETERMINE THE NORMALIZATION PARAMETER  INORM& FOR THOPT05640
     1E,/,5X,55HPOWER SPECTRAL DENSITY  PSD& OPTION YOU HAVE PREVIOUSLY,OPT05650
     2/,5X,52HCHOSEN. TWO PSD NORMALIZATION METHODS ARE AVAILABLE:,//,10OPT05660
     3X,54HMETHOD 1 -- PSD IS NORMALIZED BY THE I-NORM/TH PROCESS,/,21X,OPT05670
     429HNOISE MINUS "Q" INORM,INORM&.,/,21X,49H NOTE: "Q" IS AN OPTIMALOPT05680
     5 STATE WEIGHTING MATRIX.&,/,21X,34HIN THIS METHOD, INORM =0,1,...,OPT05690
     6NG.,//,10X,63HMETHOD 2 -- PSD IS NORMALIZED BY THE  INORM -NG&/TH OPT05700
     7MEASUREMENT,/,21X,39HNOISE MINUS "R" INORM - NG,INORM - NG&.,/,21XOPT05710
     8,51H NOTE: "R" IS AN OPTIMAL CONTROL WEIGHTING MATRIX.&,/,21X,44HIOPT05720
     9N THIS METHOD, INORM = NG + 1,...,NG + NOB.,//,10X,51HSELECT AN INOPT05730
     $TEGER FROM 0 - 16 REPRESENTING YOUR PSD,/,15X,27HNORMALIZATION REQOPT05740
     $UIREMENTS.,//,10X,53HIF PSD NORMALIZATION IS NOT DESIRED ENTER "0"OPT05750
     $  ZERO&.)                                                         OPT05760
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  830   FORMAT (5X,43HANALYSIS COMPLETE. DO YOU WANT ANOTHER RUN?,/,15X,19OPT05770
     1HTYPE "YES" OR "NO".)                                              OPT05780
  840   FORMAT (///,5X,48HDO YOU WISH TO SAVE THE "F"-MATRIX FROM THE LASTOPT05790
     1,/,5X,36HRUN TO BE USED IN THE FOLLOWING RUN?,//,5X,39HNOTE: THE MOPT05800
     2ATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCE INTOPT05810
     3ERVAL,/,5X,4CHAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27HINDOPT05820
     4IVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)            OPT05830
  850   FORMAT (///,5X,48HDO YOU WISH TO SAVE THE "H"-MATRIX FROM THE LASTOPT05840
     1,/,5X,36HRUN TO BE USED IN THE FOLLOWING RUN?,//,5X,39HNOTE: THE MOPT05850
     2ATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCE INTOPT05860
     3ERVAL,/,5X,4CHAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27HINDOPT05870
     4IVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)            OPT05880
  860   FORMAT (///,5X,48HDO YOU WISH TO SAVE THE "G"-MATRIX FROM THE LASTOPT05890
     1,/,5X,36HRUN TO BE USED IN THE FOLLOWING RUN?,//,5X,39HNOTE: THE MOPT05900
     2ATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCE INTOPT05910
     3ERVAL,/,5X,4CHAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27HINDOPT05920
     4IVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)            OPT05930
  870   FORMAT (///,5X,52HDO YOU WISH TO SAVE THE "GAMMA"-MATRIX FROM THE OPT05940
     1LAST,/,5X,36HRUN TO BE USED IN THE FOLLOWING RUN?,//,5X,39HNOTE: TOPT05950
     2HE MATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCEOPT05960
     3 INTERVAL,/,5X,40HAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27OPT05970
     4HINDIVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)        OPT05980
  872   FORMAT (///,5X,'DO YOU WISH TO SAVE THE "A"-MATRIX FROM THE LAST' OPT05990
     1    ,/,5X,36HRUN TO BE USED IN THE FOLLOWING RUN?,//,5X,39HNOTE: TOPT06000
     2HE MATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCEOPT06010
     3 INTERVAL,/,5X,40HAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27OPT06020
     4HINDIVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)        OPT06030
  874   FORMAT (///,5X,'DO YOU WISH TO SAVE THE "B"-MATRIX FROM THE LAST' OPT06040
     1    ,/,5X,36HRUN TO BE USED IN THE FOLLOWING RUN?,//,5X,39HNOTE: TOPT06050
     2HE MATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCEOPT06060
     3 INTERVAL,/,5X,40HAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27OPT06070
     4HINDIVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)        OPT06080
  880   FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" OR "NO".)OPT06090
  920   FORMAT (//,41H........OPTSYSX IS NOW TERMINATED........,//)       OPT06100
C-----------------------------------------OPTGRAPH DATA----------OPT06110
 1000  FORMAT(I1,I4,5I5)                                                 OPT06120
C-----------------------------------------------------------------OPT06130
       END                                                               OPT06140
C=================================================================OPT06150
       SUBROUTINE SETUP (BA,G,GAM,HO,NS,NC,NG,NO)                        OPT06160
C=================================================================OPT06170
       IMPLICIT REAL*8(A-H,O-Z)                                          OPT06180
       DIMENSION BA(NS,NS),G(NS,NC),GAM(NS,NG),HO(NO,NS)                 OPT06190
       COMMON /PROG/ IOL,IQ,IR,ISS,IM,ITF1,ITF2,ITF3,IFOFW,IE,IDSTAB,IDEBOPT06200
      1UG,ISET,IREG,IPSD,IYU,INORM                                       OPT06210
C-----------------------------------------------------------------OPT06220
C  FILE DEFINITIONS                                                     OPT06230
C-----------------------------------------------------------------OPT06240
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      CALL FRTCMS ('FILEDEF ','03      ','DISK    ','X29A82  ',          OPT06250
     1'DATA    ','A       ')                                             OPT06260
C-----------------------------------------------------------------------OPT06270
C   THIS IS AN EXAMPLE OF A 83 X 84 DATA FILE X29A83 DATA AI READ FROM   OPT06280
C   A USER'S DISK AND CONVERTED (FROM A "DUMMY" ARRAY NAMED 'DUM') TO A  OPT06290
C   SYMMETRIC ARRAY.  THE FORMAT STATEMENT MUST MATCH YOUR DISK DATA     OPT06300
C   FORMAT OR THE PROGRAM WILL FAIL   NOTE: ALL PROGRAM DIMENSIONS       OPT06310
C   MUST BE ENLARGED ACCORDINGLY FOR A SYSTEM OF THIS SIZE.              OPT06320
C-----------------------------------------------------------------------OPT06330
C     READ (3,10C)                                                       OPT06340
C     READ (3,100)                                                       OPT06350
      DO 20 I=1,NS                                                       OPT06360
      READ (3,50) (BA(I,J),J=1,NS)                                       OPT06370
20    CONTINUE                                                           OPT06380
C-----------------------------------------------------------------------OPT06390
C   THESE ARE EXAMPLES OF SEVERAL POSSIBLE METHODS OF ARRAY GENERATION   OPT06400
C   WITHIN SUBROUTINE SETUP.THE "GAM" ARRAY WAS SET TO ZERO SINCE NO     OPT06410
C   "NOISE" WAS PRESENT, AND THE NON-ZERO ELEMENTS OF THE "G" ARRAY WERE OPT06420
C   EXPLICITLY DEFINED. THEY COULD ALSO BE READ FROM FILES AS ABOVE.     OPT06430
C-----------------------------------------------------------------------OPT06440
      DO 40 I=1,NS                                                       OPT06450
      DO 30 J=1,NC                                                       OPT06460
      GAM(I,J)=0.0D+00                                                   OPT06470
      G(I,J)=0.0D+00                                                     OPT06480
 30   CONTINUE                                                           OPT06490
 40   CONTINUE                                                           OPT06500
      G(82,1)= 0.1000D+00                                                OPT06510
C     G(52,1)= 0.362D+07                                                 OPT06520
C     G(77,1)=-0.1591D+02                                                OPT06530
C     G(78,1)= 0.2448D+00                                                OPT06540
C     G(79,1)= 0.2448D+00                                                OPT06550
C     G(81,1)= 0.100D+00                                                 OPT06560
C-----------------------------------------------------------------------OPT06570
C     READ (3,10C)                                                       OPT06580
C     DO 70 I=1,NS                                                       OPT06590
C     READ (3,50) (G(I,J),J=1,NC)                                        OPT06600
C70   CONTINUE                                                           OPT06610
C-----------------------------------------------------------------------OPT06620
C   THIS IS AN EXAMPLE OF ONE POSSIBLE METHOD OF ARRAY GENERATION       =OPT06630
C   WITHIN THE PROGRAM ITSELF.  FOR VERY LARGE DATA ARRAYS, THIS METHOD =OPT06640
C   MAY BE PREFERABLE TO SOME USERS OVER INTERACTIVE ENTRY OF EACH       =OPT06650
C   INDIVIDUAL ELEMENT.                                                 =OPT06660
C-----------------------------------------------------------------------OPT06670
C     DO 2 I=1,11                                                        OPT06680
C        DO 1 J=1,82                                                     OPT06690
C             HO(I,J)    = 0.0D+00                                       OPT06700
C             HO(1,1)    = 0.11520D+00                                   OPT06710
C             HO(2,75)   = 0.5730D+02                                    OPT06720
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C              HO(3,74)   = 0.1000D+01                                          OPT06730
C              HO(4,63)   = 0.5730D+02                                          OPT06740
C              HO(5,62)   = 0.1000D+01                                          OPT06750
C              HO(6,76)   = 0.5730D+02                                          OPT06760
C              HO(7,44)   = 0.5730D+02                                          OPT06770
C              HO(8,45)   = 0.5730D+02                                          OPT06780
C              HO(9,46)   = 0.5730D+02                                          OPT06790
C              HO(10,47)  = 0.5730D+02                                          OPT06800
C              HO(11,48)  = 0.5730D+02                                          OPT06810
C1        CONTINUE                                                              OPT06820
C2     CONTINUE                                                                 OPT06830
C      GO TO 90                                                                 OPT06840
C3     CONTINUE                                                                 OPT06850
C-------------------------------------------------------------------------------OPT06860
C      READ (3,100)                                                             OPT06870
C      DO 90 I=1,NC                                                             OPT06880
C      READ (3,50) (HO(I,J),J=1,NS)                                             OPT06890
C90    CONTINUE                                                                 OPT06900
       RETURN                                                                   OPT06910
C-------------------------------------------------------------------------------OPT06920
50     FORMAT (5E12.4)                                                          OPT06930
C50    FORMAT (3(D22.15,3X))                                                    OPT06940
C100   FORMAT ()                                                                OPT06950
       END                                                                      OPT06960
C===============================================================================OPT06970
       SUBROUTINE CHECK (EPS,NC,NG,NO,IRET)                                     OPT06980
C      CHECKS THE CONSISTENCY OF REQUESTED OPTIONS.                            =OPT06990
C===============================================================================OPT07000
       DOUBLE PRECISION EPS                                                     OPT07010
       COMMON /PRCG/ IOL,IQ,IR,ISS,IM,ITF1,ITF2,ITF3,IFDFW,IE,IDSTAB,IDEBOPT07020
      1UG,ISET,IREG,IPSD,IYU,INORM                                              OPT07030
C-------SET MODAL ANALYSIS WHEN OL EIGENSYS OR CL TF REQUESTED----------OPT07040
       IF (IM .EQ. 1 .AND. IOL .EQ. 0) IOL=1                                    OPT07050
       IF (IOL .EQ. 3 .OR. ITF1 .NE. 0) IM=1                                    OPT07060
C----------------CHECK TO SEE IF H MATRIX INPUT----------------------OPT07070
       IF (NO .NE. 0 .OR. IOL .GE. 2) GO TO 10                                  OPT07080
       WRITE (5,90)                                                             OPT07090
       IRET=1                                                                   OPT07100
       RETURN                                                                   OPT07110
10     CONTINUE                                                                 OPT07120
C-----------------TRANSFER FUNCTION CHECKS-----------------------------OPT07130
       IF (IE .EQ. 0) IE=6                                                      OPT07140
       EPS=10.**(-IE)                                                           OPT07150
C--------------------OPEN LOOP TF-----------------------------------OPT07160
       IF (ITF1 .EQ. 0 .OR. NC .NE . 0) GO TO 20                                OPT07170
       WRITE (5,100)                                                            OPT07180
       IRET=1                                                                   OPT07190
       RETURN                                                                   OPT07200
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C----------------------COMPENSATOR TF-----------------------------------OPT07210
20    IF (ITF3 .EQ. 0) GO TO 30                                          OPT07220
      IF (IREG .EQ. 0 .AND. (NC .NE. 0 .AND. NG .NE. 0)) GO TO 30        OPT07230
      WRITE (5,11C)                                                      OPT07240
      IRET=1                                                             OPT07250
      RETURN                                                             OPT07260
30    CONTINUE                                                           OPT07270
C----------------------NOISE TF-----------------------------------------OPT07280
      IF (ITF2 .EQ. 0) GO TO 40                                          OPT07290
      IF (NG.NE. 0 .AND. NC .NE. 0) GO TO 40                             OPT07300
      WRITE (5,12C)                                                      OPT07310
      IRET=1                                                             OPT07320
      RETURN                                                             OPT07330
C-----------------DESTABILIZATION RESTRICTIONS--------------------------OPT07340
4C    IF (IDSTAB .EQ. 0) GO TO 50                                        OPT07350
      IF (NC .EQ. 0) GO TO 50                                            OPT07360
      IF (NG .NE. 0) IREG=1                                              OPT07370
      WRITE (5,13C)                                                      OPT07380
      IF (IREG .EC. 1) GO TO 50                                          OPT07390
      IRET=1                                                             OPT07400
      RETURN                                                             OPT07410
5C    CONTINUE                                                           OPT07420
C-----------------PSD INPUT---------------------------------------------OPT07430
      IF (IPSD .EC. 0) GO TO 80                                          OPT07440
      IF (IPSD .LT. 0 .OR. IPSD .GT. 3) GO TO 60                         OPT07450
      IF (IYU .LT. 0 .OR. IYU .GT. 3) GO TO 60                           OPT07460
      IF (INORM .LT. 0 .OR. INORM .GT. NG+NO) GO TO 60                   OPT07470
      GO TO 70                                                           OPT07480
6C    WRITE (5,14C)                                                      OPT07490
      IRET=1                                                             OPT07500
      RETURN                                                             OPT07510
7C    IF (IREG .EC. 0 .AND. NC .NE. 0) GO TO 80                          OPT07520
      WRITE (5,15C)                                                      OPT07530
      IRET=1                                                             OPT07540
      RETURN                                                             OPT07550
8C    CONTINUE                                                           OPT07560
      RETURN                                                             OPT07570
C------------------------------------------------------------------------OPT07580
90    FORMAT (//,5X,49H H - MATRIX MUST BE INPUT, I.E. "NC" MUST BE > 0.OPT07590
     1,//)                                                               OPT07600
100   FORMAT (//,5X,46H(G) MATRIX MUST BE INPUT, I.E. NC MUST BE > 0.,/,OPT07610
     110X,26HTO COMPUTE OPEN LOOP T. F.,//)                              OPT07620
110   FORMAT (//,5X,48HREGULATOR AND FILTER SYNTHESIS MUST BE REQUESTED,OPT07630
     1/,5X,44HIN THE SAME RUN TO COMPUTE COMPENSATOR T. F.,/,5X,47HI.E. OPT07640
     2IREG MUST = 0.; "NC" AND "NG" MUST BE > C.,//)                     OPT07650
120   FORMAT (//,5X,51HNOISE T. F. CALCULATED ONLY WHEN REGULATOR DESIGNOPT07660
     1ED,/,5X,47HI.E. IREG MUST = 1.; "NC" AND "NG" MUST BE > 0.,//)     OPT07670
130   FORMAT (//,5X,47HDESTABILIZATION OPTION DESIGNED FOR A REGULATOR,/OPT07680
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     1,5X,38HOR FILTER BUT NOT BOTH SIMULTANEOUSLY.,//,5X,55HIF "NG" > 0OPT07690
     2. THE REGULATOR OPTION IS AUTOMATICALLY SET ,//)                  OPT07700
14C   FORMAT (//,5X,49H ********** INCONSISTENT PSD INPUT FLAGS ********OPT07710
     1,//)                                                              OPT07720
150   FORMAT (//,5X,44HBOTH A REGULATOR AND FILTER MUST BE RESIDENT,/,10OPT07730
     1X,42HTO COMPUTE THE PSD OF A CONTROLLED SYSTEM ,/,10X,42HI.E. IREGOPT07740
     2 MUST BE 0. AND "NC" MUST BE > 0.,//)                             OPT07750
      END                                                               OPT07760
C=====================================================================OPT07770
      SUBROUTINE INNER (NS,NC,NO,NG,N2,ACL,B,BA,CI,CR,CQ,CWI,CWR,D,FBGC,OPT07780
     1FBGE,G,GAM,GM,GN,HC,D1,D2,PRC,RM,RC,Q,SC,WR,WI,W11,W21,X,WNORM,WNOOPT07790
     2RMI,DESTAB,AA,BM,CM,JCF,RES,AY,BB,CC,CP,GW,GV,HY,HU,DSTORE,ISAF,ISOPT07800
     3AH,ISAG,IGAM,IRET,PRTT,NROW,NCOL,IRDMAT,ISAA,ISAB)                OPT07810
C=====================================================================OPT07820
      IMPLICIT REAL*8(A-H,C-Z)                                          OPT07830
C---------------------------------------------------------------------OPT07840
      DIMENSION ACL(NS,NS),B(NC,NC),BA(NS,NS),CI(NS),CR(NS),CQ(NS,NS),CWOPT07850
     1I(NS),CWR(NS),FBGC(NC,NS),FBGE(NS,NO),G(NS,NS),GM(NS,NS),PRC(NS,NSOPT07860
     2),RC(NC,NO),SC(NS,NS),WR(N2),WI(N2),W11(NS,NS),W21(NS,NS),X(N2,N2)OPT07870
     3,GN(NS,NS),HO(NO,NS),D1(N2),D2(N2),RM(N2,N2),G(NG,NG),D(NC,NC),GAMOPT07880
     4(NS,NG),WNORM(NS,NS),WNORMI(NS,NS),DESTAB(NS),AA(NS,NS),BM(NS,NC),OPT07890
     5CM(NO,NS),JCF(N2),RES(N2),AY(NO,NO),BB(N2),CC(N2),CP(NS),GW(N2,NG)OPT07900
     6,GV(N2,NO),HY(NO,N2),HU(NC,N2),DSTORE(NS,NS),PRTT(16,16)          OPT07910
C---------------------------------------------------------------------OPT07920
      COMMON /PROC/ IOL,IQ,IR,ISS,IM,ITF1,ITF2,ITF3,IFDFW,IE,IDSTAB,IDEBOPT07930
     1UG,ISET,IREG,IPSD,IYL,INORM                                       OPT07940
C---------------------------------------------------------------------OPT07950
      REAL*4 FMT(20)                                                    OPT07960
C--------------------OUTPUT OPTIONS-----------------------------------OPT07970
C---IOL=1 IF THE OPEN LOOP EIGENSYSTEM IS DESIRED--OTHERWISE IOL=0      OPT07980
C---IQ=1 IF THE RMS VALUES OF THE CONTROL AND STATE ARE TO BE FOUND     OPT07990
C---IR=0 IF OPTIMAL FILTER AND REGULATOR EIGENSYSTEMS ARE TO BE FOUND   OPT08000
C---IR=1 IF EXTERNAL C MATRIX IS SUPPLIED                              OPT08010
C---IR=2 IF EXTERNAL K IS SUPPLIED                                     OPT08020
C---IR=3 IF EXTERNAL C AND K ARE SUPPLIED                              OPT08030
C---ISS=1 IF STEADY STATE VALUES ARE TO BE DETERMINED                  OPT08040
C---IM=1 IF MODAL STATES DESIRED                                       OPT08050
C---------------------------------------------------------------------OPT08060
      NSQ=NS*NS                                                         OPT08070
      MH=NS                                                             OPT08080
      M=N2                                                              OPT08090
      CALL CHECK (EPS,NC,NG,NO,IRET)                                    OPT08100
      IF (IRET.EQ.1) RETURN                                             OPT08110
      IF (ISET.EQ.1) GO TO 20                                           OPT08120
      CALL RDMAT(BA,G,HO,GAM,FBGC,FBGE,AY,B,NS,NC,NC,NG,IRDMAT)         OPT08130
      CALL READF (NS,ISAF,BA)                                           OPT08140
      IF (IDSTAB.EQ.0) GO TO 10                                         OPT08150
      WRITE (5,1800)                                                    OPT08160
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      CALL RDREAL (ANSR)                                                OPT08170
      DSTAB=ANSR                                                        OPT08180
      DO 10 I=1,NS                                                      OPT08190
      DESTAB(I)=DSTAB                                                   OPT08200
10    CONTINUE                                                          OPT08210
      GO TO 30                                                          OPT08220
20    CALL SETUP (BA,G,GAM,HO,NS,NC,NG,NO)                              OPT08230
30    CONTINUE                                                          OPT08240
      WRITE (6,1380)                                                    OPT08250
      DO 40 I=1,NS                                                      OPT08260
40    WRITE (6,1390) (BA(I,J),J=1,NS)                                   OPT08270
      IF (IDSTAB.EQ.0) GO TO 50                                         OPT08280
      WRITE (6,1480)                                                    OPT08290
      WRITE (6,1390) (DESTAB(I),I=1,NS)                                 OPT08300
50    CONTINUE                                                          OPT08310
C-------------EIGENSYSTEM OF THE OPEN LOOP DYNAMICS-------------------OPT08320
      IF (IOL.EQ.0.AND.IQ.EQ.0) GO TO 90                                OPT08330
      IF (IOL.EQ.0.AND.NC.NE.0) GO TO 90                                OPT08340
      DO 60 I=1,NS                                                      OPT08350
      DO 60 J=1,NS                                                      OPT08360
60    GN(I,J)=BA(I,J)                                                   OPT08370
      CALL BALANC (NS,NS,GN,LOW,IHIGH,D1)                               OPT08380
      CALL ORTHES (NS,NS,LOW,IHIGH,GN,D2)                               OPT08390
      CALL ORTRAN (NS,NS,LOW,IHIGH,GN,D2,SC)                            OPT08400
      CALL HQR2 (NS,NS,LOW,IHIGH,GN,CWR,CWI,SC,IERR)                    OPT08410
      IF (IERR.NE.0) CALL EREXIT (NS,GN,IERR)                           OPT08420
      CALL BALBAK (NS,NS,LOW,IHIGH,D1,NS,SC)                            OPT08430
C----------NORMALIZE AND PRINT OPEN LOOP EIGENSYSTEM-----------------OPT08440
      IWRITE=1                                                          OPT08450
      CALL CNORM (CWR,CWI,SC,NS,IWRITE,NSQ,DDD,D1,D2,WNORM,WNORMI,FC,CM,OPT08460
     1NO,NS)                                                            OPT08470
C-------------------------------------------------CPTGRCL/CPTGRNO DATA---OPT08480
      DO 64 I = 1,NS                                                    OPT08490
         WRITE (10,2000) CWR(I), CWI(I)                                 OPT08500
         WRITE (1,2000) CWR(I), CWI(I)                                  OPT08510
64    CONTINUE                                                          OPT08520
C-----------------------------------------------------------------------OPT08530
      IF (IOL.EQ.2) RETURN                                              OPT08540
      IF (IQ.EQ.0.OR.(NC.NE.0.OR.IDSTAB.GT.0)) GO TO 90                 OPT08550
      DO 70 I=1,NS                                                      OPT08560
      IF (CWR(I).LT.0.) GO TO 70                                        OPT08570
      WRITE (5,1490)                                                    OPT08580
      RETURN                                                            OPT08590
70    CONTINUE                                                          OPT08600
      IF (IOL.EQ.2) GO TO 130                                           OPT08610
      DO 80 I=1,NS                                                      OPT08620
      DO 80 J=1,NS                                                      OPT08630
80    W11(I,J)=SC(I,J)                                                  OPT08640
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      CALL MINV (NSQ,W11,NS,DDD,D1,D2)                                  OPT08650
 90   CONTINUE                                                          OPT08660
      IF (IDSTAB.EQ.0) GO TO 130                                        OPT08670
C---------------- FORM U * DIAG(DESTAB) * U-INV-----------------------OPT08680
      DO 100 J=1,NS                                                     OPT08690
      DO 100 I=1,NS                                                     OPT08700
100   AA(I,J)=WNORM(I,J)*DESTAB(J)                                      OPT08710
      DO 120 I=1,NS                                                     OPT08720
      DO 120 J=1,NS                                                     OPT08730
      DDD=0.D0                                                          OPT08740
      DO 110 K=1,NS                                                     OPT08750
110   DDD=DDD+AA(I,K)*WNORMI(K,J)                                       OPT08760
      DSTORE(I,J)=DDD                                                   OPT08770
120   BA(I,J)=BA(I,J)+DDD                                               OPT08780
130   CONTINUE                                                          OPT08790
      IF (NO.EQ.0) GO TO 145                                            OPT08800
      IF (ISET.EQ.1) GO TO 135                                          OPT08810
      CALL READH (NO,NS,ISAH,HO)                                        OPT08820
135   CONTINUE                                                          OPT08830
      WRITE (6,1440)                                                    OPT08840
      DO 140 I=1,NO                                                     OPT08850
140   WRITE (6,1390) (HO(I,J),J=1,NS)                                   OPT08860
145   IF (IM.NE.1) GO TO 150                                            OPT08870
      CALL MODE (WNORM,HO,CM,NS,NO,NS,2)                                OPT08880
150   CONTINUE                                                          OPT08890
      IF (IFCFW.EQ.0) GO TO 170                                         OPT08900
      CALL READD (NO,NC,D)                                              OPT08910
      WRITE (6,1470)                                                    OPT08920
      DO 160 I=1,NO                                                     OPT08930
160   WRITE (6,1390) (D(I,J),J=1,NC)                                    OPT08940
170   CONTINUE                                                          OPT08950
      NOB=0                                                             OPT08960
      IF (NC.EQ.0) GO TO 590                                            OPT08970
      IF (IOL.EQ.3) GO TO 270                                           OPT08980
      IF (IR.NE.1.AND.IR.NE.3) GO TO 210                                OPT08990
      IF (ISET.EQ.1) GO TO 180                                          OPT09000
      CALL READG (NS,NC,ISAG,G)                                         OPT09010
180   CONTINUE                                                          OPT09020
      CALL READFB (NC,NS,FBGC)                                          OPT09030
      WRITE (6,1400)                                                    OPT09040
      DO 190 I=1,NS                                                     OPT09050
190   WRITE (6,1390) (G(I,J),J=1,NC)                                    OPT09060
      IF (IM.NE.1) GO TO 200                                            OPT09070
      CALL MODE (WNORMI,G,BM,NS,NS,NC,0)                                OPT09080
200   CONTINUE                                                          OPT09090
      GO TO 330                                                         OPT09100
210   DO 220 I=1,NS                                                     OPT09110
      DO 220 J=1,NS                                                     OPT09120
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220   RM(I+MH,J)=C.0                                                    OPT09130
      CALL READAY (NO,ISAA,AY)                                          OPT09140
      DO 240 I=1,NC                                                     OPT09150
      DO 240 J=1,NS                                                     OPT09160
      DDD=0.D0                                                          OPT09170
      DO 230 K=1,NC                                                     OPT09180
230   DDD=DDD+AY(I,K)*HO(K,J)                                           OPT09190
240   AA(I,J)=DDD                                                       OPT09200
      WRITE (6,1460)                                                    OPT09210
      DO 250 I=1,NC                                                     OPT09220
250   WRITE (6,1390) (AY(I,J),J=1,NO)                                   OPT09230
      DO 260 I=1,NS                                                     OPT09240
      DO 260 J=1,NS                                                     OPT09250
      DO 260 K=1,NC                                                     OPT09260
260   RM(I+MH,J)=RM(I+MH,J)+AA(K,I)*HO(K,J)                             OPT09270
270   IF (ISET.EQ.1) GO TO 280                                          OPT09280
      CALL READG (NS,NC,ISAG,G)                                         OPT09290
280   CONTINUE                                                          OPT09300
      IF (IOL.EQ.3) GO TO 290                                           OPT09310
      CALL READB (NC,ISAB,B)                                            OPT09320
290   WRITE (6,1400)                                                    OPT09330
      DO 300 I=1,NS                                                     OPT09340
300   WRITE (6,1390) (G(I,J),J=1,NC)                                    OPT09350
      IF (IM.NE.1) GO TO 310                                            OPT09360
      CALL MODE (WNORMI,G,BM,NS,NS,NC,0)                                OPT09370
310   CONTINUE                                                          OPT09380
      IF (IOL.EQ.3) GO TO 340                                           OPT09390
      WRITE (6,1410)                                                    OPT09400
      DO 320 I=1,NC                                                     OPT09410
320   WRITE (6,1390) (B(I,J),J=1,NC)                                    OPT09420
330   IF (ITF1.EQ.0) GO TO 350                                          OPT09430
C-----------------OPEN LOOP TRANSFER FUNCTIONS-------------------------OPT09440
340   WRITE (6,1500)                                                    OPT09450
      ITFX=1                                                            OPT09460
      CALL TF (NS,NS,NSQ,BA,AA,NC,G,BM,NO,HO,CM,IFDFW,D,BB,CC,CP,WR,WI,COPT09470
     1WR,CWI,SC,JCF,RES,D1,D2,DDD,EPS,ITF1,ITFX)                        OPT09480
350   IF (IOL.NE.3) GO TO 360                                           OPT09490
      IF (NG.EQ.0) RETURN                                               OPT09500
      GO TO 600                                                         OPT09510
360   CONTINUE                                                          OPT09520
      IF (IR.EQ.1.OR.IR.EQ.3) GO TO 500                                 OPT09530
C---CALCULATION OF CONTROL GAINS:FORMATION OF CONTROL HAMILTONIAN-------OPT09540
C                                                                       OPT09550
C   ┌                          ┐          ***F AND FT ARE THE OPEN LOOP OPT09560
C   │     F        -GM*BI*GMT  │             DYNAMICS MATRIX AND TRANSPOSE OPT09570
C   │                          │          ***BI IS NCXNC CONTROL WEIGHTING OPT09580
C   │                          │             MATRIX                    OPT09590
C   │                          │          ***A IS THE NSXNS STATE WEIGHTINGOPT09600
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C     |                                    |             MATRIX                           OPT09610
C     |_     -A                  -FT     _|                                              OPT09620
C     ---                               ---         ***GM IS THE NSXNC CONTROL          OPT09630
C                                                      DISTRIBUTION MATRIX              OPT09640
C-----------------------------------------------------------------------------------OPT09650
      DO 370 I=1,NC                                                                 OPT09660
      DO 370 J=1,MH                                                                 OPT09670
370   PRO(I,J)=G(J,I)/B(I,I)                                                        OPT09680
      DO 380 I=1,MH                                                                 OPT09690
      DO 380 J=1,MH                                                                 OPT09700
      RM(I,J+MH)=0.D0                                                               OPT09710
      DO 380 K=1,NC                                                                 OPT09720
380   RM(I,J+MH)=RM(I,J+MH)-G(I,K)*PRO(K,J)                                         OPT09730
C-----------------2NX2N HAMILTONIAN MATRIX-------------------------------------------OPT09740
C---------------DIAGONAL BLOCKS---M11 AND M22-----------------------------------------OPT09750
      DO 390 I=1,MH                                                                 OPT09760
      DO 390 J=1,MH                                                                 OPT09770
      RM(I,J)=BA(I,J)                                                               OPT09780
      RM(I+MH,J+MH)=-BA(J,I)                                                        OPT09790
C-------------------------M21 BLOCK-------------------------------------------------OPT09800
390   RM(I+MH,J)=-RM(I+MH,J)                                                        OPT09810
C--------------M12 BLOCK IS DEFINED IN LINE 430 ABOVE---------------------------------OPT09820
400   CONTINUE                                                                      OPT09830
      IF (IDEBUG.EQ.0) GO TO 410                                                    OPT09840
      WRITE (6,1510)                                                                OPT09850
      CALL RAPRNT (M,M,M,9,RM,4,'(9(1X,1PD13.6))')                                  OPT09860
410   CALL BALANC (M,M,RM,LOW,IHIGH,D1)                                             OPT09870
      CALL ORTHES (M,M,LOW,IHIGH,RM,D2)                                             OPT09880
      CALL ORTRAN (M,M,LOW,IHIGH,RM,D2,X)                                           OPT09890
      CALL HQR2 (M,M,LOW,IHIGH,RM,WR,WI,X,IERR)                                     OPT09900
      IF (IERR .NE. 0) CALL EREXIT (M,RM,IERR)                                      OPT09910
      CALL BALBAK (M,M,LOW,IHIGH,D1,M,X)                                            OPT09920
C-----------DEBUG DIAGNOSTICS ON EULER-LAGRANGE EQUATIONS-----------------------------OPT09930
      IF (IDEBUG .EQ. 0) GO TO 430                                                  OPT09940
      WRITE (6,1520)                                                                OPT09950
      DO 420 I=1,M                                                                  OPT09960
420   WRITE (6,1530) WR(I),WI(I)                                                    OPT09970
      WRITE (6,1540)                                                                OPT09980
      CALL RAPRNT (M,M,M,9,X,4,'(9(1X,1PD13.6))')                                   OPT09990
430   CONTINUE                                                                      OPT10000
      IF (IDSTAB .EQ. 1) GO TO 440                                                  OPT10010
      IF (NOB.EQ.0) WRITE (6,1550)                                                  OPT10020
      IF (NOB.NE.0) WRITE (6,1560)                                                  OPT10030
440   IF (NOB.NE. 0) GO TO 750                                                      OPT10040
      CALL RGAIN (M,NS,NC,NOB,WR,WI,X,GN,W11,RM,W21,D1,CWR,CWI,SC,MHS,D2OPT10050
     1)                                                                             OPT10060
C------------------------CHECK EIGENVECTORS------------------------------------------OPT10070
      IF (IDEBUG .EQ. 0) GO TO 450                                                  OPT10080
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      WRITE (6,1570)                                                    OPT10090
      CALL RAPRNT (NS,NS,NS,9,SC,4,'(9(1X,1PD13.6))')                   OPT10100
450   CONTINUE                                                          OPT10110
C------RESET FLAG AND F MATRIX FOR ITERATIVE DESTABILIZATION CASE-------OPT10120
      IF (IDSTAB .EQ. 0) GO TO 470                                      OPT10130
      DO 460 I=1,NS                                                     OPT10140
460   BA(I,I)=BA(I,I)-DESTAB(I)                                         OPT10150
      IR=1                                                              OPT10160
470   CONTINUE                                                          OPT10170
C------------------CALCULATION OF FEEDBACK GAIN-------------------------OPT10180
C-------------FEEDBACK GAINS--->  U = -(BINVERSE)*GT*GN&-----------------OPT10190
C---------------------CALCULATE GT-------------------------------------OPT10200
      DO 490 I=1,NC                                                     OPT10210
      DO 490 J=1,NS                                                     OPT10220
      PRO(I,J)=0.D0                                                     OPT10230
      DO 480 K=1,MH                                                     OPT10240
480   PRO(I,J)=PRO(I,J)+G(K,I)*GN(K,J)                                  OPT10250
490   FBGC(I,J)=-PRO(I,J)/B(I,I)                                        OPT10260
      IF (IDSTAB .EQ. 1) GO TO 500                                      OPT10270
C---------NORMALIZE AND PRINT OPT. REG. CLOSED LOOP EIGENSYSTEM---------OPT10280
      IWRITE=2                                                          OPT10290
      CALL CNORM (CWR,CWI,SC,NS,IWRITE,NSQ,DDD,D1,D2,WNORM,WNORMI,FBGC, OPT10300
     1AA,NC,NS)                                                         OPT10310
C----------------THE OPTIMUM FEEDBACK CONTROL GAINS--------------------OPT10320
500   WRITE (6,1580)                                                    OPT10330
      DO 510 I=1,NC                                                     OPT10340
510   WRITE (6,1590) (FBGC(I,J),J=1,NS)                                 OPT10350
C------COMPUTE MODAL C MATRIX  OPEN LOOP U-INVERSE SAVED IN WNORMI&-----OPT10360
      IF (IM .NE. 1) GO TO 530                                          OPT10370
C-----------------------------------------------------------------------OPT10380
C IN COMPUTING MODAL C RECOMPUTE U OPEN LOOP SINCE WNORM USED TO STORE  OPT10390
C U & U-INV FOR CLOSED LOOP SYSTEMS; WNORMI USED TO SAVE U-INV OPEN LOOPOPT10400
C-----------------------------------------------------------------------OPT10410
      DO 520 I=1,NS                                                     OPT10420
      DO 520 J=1,NS                                                     OPT10430
520   WNORM(I,J)=WNORMI(I,J)                                            OPT10440
      CALL MINV (NSQ,WNORM,NS,DDD,D1,D2)                                OPT10450
      CALL MODE (WNORM,FBGC,AA,NS,NC,NS,3)                              OPT10460
530   CONTINUE                                                          OPT10470
C-----------------THE CLOSED LOOP DYNAMICS MATRIX---------------------OPT10480
      DO 550 I=1,NS                                                     OPT10490
      DO 550 J=1,NS                                                     OPT10500
      SUM=0.D0                                                          OPT10510
      DO 540 K=1,NC                                                     OPT10520
540   SUM=SUM+G(I,K)*FBGC(K,J)                                          OPT10530
550   ACL(I,J)=BA(I,J)+SUM                                              OPT10540
      WRITE (6,1600)                                                    OPT10550
      CALL RAPRNT (MH,MH,MH,5,ACL,4,'(5(1X,1PD13.6))')                  OPT10560
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      IF (IR.NE.1.AND.IR.NE.3) GO TO 590                                OPT10570
      DO 560 I=1,NS                                                     OPT10580
      DO 560 J=1,NS                                                     OPT10590
560   GN(I,J)=ACL(I,J)                                                  OPT10600
      CALL BALANC (NS,NS,GN,LOW,IHIGH,D1)                               OPT10610
      CALL ORTHES (NS,NS,LOW,IHIGH,GN,D2)                               OPT10620
      CALL ORTRAN (NS,NS,LOW,IHIGH,GN,D2,SC)                            OPT10630
      CALL HQR2 (NS,NS,LOW,IHIGH,GN,CWR,CWI,SC,IERR)                    OPT10640
      IF (IERR .NE. 0) CALL EREXIT (NS,GN,IERR)                         OPT10650
      CALL BALBAK (NS,NS,LOW,IHIGH,D1,NS,SC)                            OPT10660
C-------NORMALIZE AND PRINT CLOSED LOOP SUBOPT. REG. EIGENSYSTEM--------OPT10670
      IWRITE=3                                                          OPT10680
      CALL CNORM (CWR,CWI,SC,NS,IWRITE,NSQ,DDD,D1,D2,WNORM,WNCRMI,FBGC, OPT10690
     1AA,NC,NS)                                                         OPT10700
      DO 570 I=1,NS                                                     OPT10710
      IF (CWR(I).LT.0.0) GO TO 570                                      OPT10720
      WRITE (5,1610)                                                    OPT10730
      RETURN                                                            OPT10740
570   CONTINUE                                                          OPT10750
      IF (IQ.NE.1) GO TO 590                                            OPT10760
      DO 580 I=1,NS                                                     OPT10770
      DO 580 J=1,NS                                                     OPT10780
580   W11(I,J)=SC(I,J)                                                  OPT10790
      CALL MINV (NSQ,W11,NS,DDD,D1,D2)                                  OPT10800
590   NCB=NO                                                            OPT10810
      IF ( NG .EQ. 0) RETURN                                            OPT10820
600   IF (ISET.EQ.1) GO TO 610                                          OPT10830
      CALL READG2 (NS,NG,IGAM,GAM)                                      OPT10840
610   CONTINUE                                                          OPT10850
      IF (IOL .EQ. 3) GO TO 620                                         OPT10860
      CALL READQ (NG,Q)                                                 OPT10870
620   WRITE (6,1420)                                                    OPT10880
      DO 630 I=1,NS                                                     OPT10890
630   WRITE (6,1390) (GAM(I,J),J=1,NG)                                  OPT10900
      IF (IM.NE.1) GO TO 640                                            OPT10910
      CALL MCDE (WNORMI,GAM,AA,NS,NS,NG,1)                              OPT10920
640   CONTINUE                                                          OPT10930
      IF (IOL .EQ. 3) RETURN                                            OPT10940
      WRITE (6,1420)                                                    OPT10950
      DO 650 I=1,NG                                                     OPT10960
650   WRITE (6,1390) (Q(I,J),J=1,NG)                                    OPT10970
      IF ((IQ.EQ.0).AND.(NC.EQ.0)) GO TO 1260                           OPT10980
      DO 660 I=1,NG                                                     OPT10990
      DO 660 J=1,NS                                                     OPT11000
      PRO(I,J)=0.00                                                     OPT11010
      DO 660 K=1,NG                                                     OPT11020
660   PRO(I,J)=PRO(I,J)+Q(I,K)*GAM(J,K)                                 OPT11030
      DO 670 I=1,NS                                                     OPT11040
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      DO 670 J=1,NS                                                          OPT11050
      CQ(I,J)=0.CC                                                           OPT11060
      DO 670 K=1,NG                                                          OPT11070
670   CQ(I,J)=CQ(I,J)-GAM(I,K)*PRO(K,J)                                      OPT11080
      IF (IREG .EC. 1) GC TO 690                                             OPT11090
C---CALCULATION CF FILTER GAINS:FORMATION OF ESTIMATION HAMILTONIAN-----OPT11100
C                                                                        =OPT11110
C    ┌--                          --┐          ***F AND FT ARE SAME AS FCR  =OPT11120
C    |    F          -GM*Q*GMT      |             CONTROL HAMILTONIAN       =OPT11130
C    |                              |          ***Q IS NGXNG STATE DISTURBANCE=OPT11140
C    |                              |             RCOVARIANCE               =OPT11150
C    |                              |          ***R IS NOXNO MEASUREMENT NOISE=OPT11160
C    | -HOT*RIN*HC       -FT        |             RCOVARIANCE               =OPT11170
C    └--                          --┘          ***HO IS NCXNS MEASUREMENT MATRIX=OPT11180
C                                              ***GM IS NSXNG STATE DISTURBANCE =OPT11190
C                                                 DISTRIBUTICN MATRIX        =OPT11200
C--------------------------------------------------------------------OPT11210
      CALL READR (NO,RC)                                                     OPT11220
      WRITE (6,1450)                                                         OPT11230
      DO 680 I=1,NC                                                          OPT11240
680   WRITE (6,1350) (RC(I,J),J=1,NO)                                        OPT11250
690   IF (ITF2 .EC. 0) GO TO 700                                             OPT11260
C-----------------NOISE TRANSFER FUNCTIONS-----------------------OPT11270
      WRITE (6,1620)                                                         OPT11280
      ITFX=2                                                                 OPT11290
      IZERO=0                                                                OPT11300
      CALL TF (NS,NS,NSQ,ACL,AA,NG,GAM,BM,NO,HC,CM,IZERC,D,BB,CC,CF,WR,      OPT11310
     1WI,CWR,CWI,SC,JCF,RES,D1,D2,DDD,EPS,ITF2,ITFX)                         OPT11320
      IF (IREG .EC. 1) RETURN                                                OPT11330
700   CONTINUE                                                               OPT11340
      IF (IREG .EC. 1) GO TO 930                                             OPT11350
      IF (IR.LT.2) GO TO 710                                                 OPT11360
      CALL READFE (NS,NO,FBGE)                                               OPT11370
      GO TO 810                                                              OPT11380
710   CONTINUE                                                               OPT11390
C-----------THE MEASUREMENT MATRIX (HOT*RIN*HO===>SC-------------------OPT11400
      DO 720 I=1,NC                                                          OPT11410
      DO 720 J=1,MH                                                          OPT11420
720   PRO(I,J)=HC(I,J)/RC(I,I)                                               OPT11430
      DO 730 I=1,MH                                                          OPT11440
      DO 730 J=1,MH                                                          OPT11450
      RM(I+MH,J)=C.DO                                                        OPT11460
      DO 730 K=1,NO                                                          OPT11470
730   RM(I+MH,J)=RM(I+MH,J)-HO(K,I)*PRO(K,J)                                 OPT11480
C-------------------------GM*Q*GMT===>CC---------------------------OPT11490
      DO 740 I=1,NS                                                          OPT11500
      DO 740 J=1,NS                                                          OPT11510
      RM(I,J)=BA(I,J)                                                        OPT11520
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      RM(I+MH,J+MH)=-BA(J,I)                                                OPT11530
740   RM(I,J+NS)=CC(I,J)                                                    OPT11540
      GO TO 400                                                             OPT11550
C-GO BACK TO 450 TO SET UP THE FILTER HAMILTONIAN; CALC.THE FILTER GAINSOPT11560
750   CALL RGAIN (M,NS,NC,NCB,WR,WI,X,GN,GM ,RM,W21,D1,CR,CI,PRO,MHS,D2)OPT11570
C----------------------CHECK EIGENVECTORS-----------------------------OPT11580
      IF (IDEBUG .EQ. 0) GO TO 760                                          OPT11590
      WRITE (6,1570)                                                        OPT11600
      CALL RAPRNT (NS,NS,NS,9,PRO,4,'(9(1X,1PD13.6))')                      OPT11610
760   CONTINUE                                                              OPT11620
      IF (IDSTAB .EQ. 1) GO TO 770                                          OPT11630
C------------NORMALIZE AND PRINT OPT. ESTIMATOR EIGENSYSTEM-------------OPT11640
      IWRITE=4                                                              OPT11650
      CALL CNORM (CR,CI,PRO,NS,IWRITE,NSQ,DDD,D1,D2,WNORM,WNORMI,HC,AA,     OPT11660
     1NC,NS)                                                                OPT11670
770   DO 780 I=1,MH                                                         OPT11680
      DO 780 J=1,NO                                                         OPT11690
780   PRO(I,J)=+HC(J,I)/RC(J,J)                                             OPT11700
      DO 790 I=1,MH                                                         OPT11710
      DO 790 J=1,NO                                                         OPT11720
      FBGE(I,J)=0.D0                                                        OPT11730
      DO 790 K=1,MH                                                         OPT11740
790   FBGE(I,J)=FBGE(I,J)+GN(I,K)*PRO(K,J)                                  OPT11750
      IF (IDSTAB .EQ. 1) GO TO 810                                          OPT11760
      WRITE (6,1670)                                                        OPT11770
      CALL RAPRNT (MH,MH,MH,5,GN,4,'(5(1X,1PD13.6))')                       OPT11780
      WRITE (6,1680)                                                        OPT11790
      DO 800 I=1,MH                                                         OPT11800
800   X(I,I)=DSQRT(GN(I,I))                                                 OPT11810
      WRITE (6,1690) (X(I,I),I=1,MH)                                        OPT11820
810   WRITE (6,1630)                                                        OPT11830
      DO 820 I=1,MH                                                         OPT11840
820   WRITE (6,1640) (FBGE(I,J),J=1,NO)                                     OPT11850
C--------COMPUTE MODAL K MATRIX  OPEN LOOP U-INV SAVED IN WNORMI&-------OPT11860
      IF (IM .NE. 1) GO TO 830                                              OPT11870
      CALL MODE (WNORMI,FBGE,AA,MH,MH,NO,4)                                 OPT11880
830   CONTINUE                                                              OPT11890
C------RESET FLAG AND F MATRIX FOR ITERATIVE DESTABILIZATION CASE-------OPT11900
      IF (IDSTAB .EQ. 0) GO TO 850                                          OPT11910
      DO 840 I=1,NS                                                         OPT11920
      DO 840 J=1,NS                                                         OPT11930
840   BA(I,J)=BA(I,J)-DSTORE(I,J)                                           OPT11940
      IR=2                                                                  OPT11950
850   CONTINUE                                                              OPT11960
      DO 870 I=1,NS                                                         OPT11970
      DO 870 J=1,NS                                                         OPT11980
      SUM=0.0                                                               OPT11990
      DO 860 K=1,NC                                                         OPT12000
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      SUM=SUM+FBGE(I,K)*HC(K,J)                                          OPT12010
870   PRO(I,J)=BA(I,J)-SUM                                               OPT12020
      WRITE (6,1650)                                                     OPT12030
      CALL RAPRNT (NS,NS,NS,5,PRO,4,'(5(1X,1PD13.6))')                   OPT12040
      IF (IR .LT. 2) GO TO 890                                           OPT12050
      CALL BALANC (NS,NS,PRO,LOW,IHIGH,D1)                               OPT12060
      CALL ORTHES (NS,NS,LOW,IHIGH,PRO,D2)                               OPT12070
      CALL ORTRAN (NS,NS,LOW,IHIGH,PRO,D2,GM)                            OPT12080
      CALL HQR2 (NS,NS,LOW,IHIGH,PRO,CR,CI,GM,IERR)                      OPT12090
      IF (IERR .NE. 0) CALL EREXIT (NS,PRO,IERR)                         OPT12100
      CALL BALBAK (NS,NS,LOW,IHIGH,D1,NS,GM)                             OPT12110
      WRITE (6,1560)                                                     OPT12120
C-----------NORMALIZE AND PRINT SUBOPT. ESTIMATOR EIGENSYSTEM----------OPT12130
      IWRITE=5                                                           OPT12140
      CALL CNORM (CR,CI,GM,NS,IWRITE,NSQ,DDD,D1,D2,WNORM,WNORMI,HC,AA,   OPT12150
     1NO,NS)                                                             OPT12160
      DO 880 I=1,NS                                                      OPT12170
      IF (CR(I).LT.0.0) GO TO 880                                        OPT12180
      WRITE (5,1660)                                                     OPT12190
      RETURN                                                             OPT12200
880   CONTINUE                                                           OPT12210
      GO TO 900                                                          OPT12220
890   IF (IQ.EQ.0) GO TO 1260                                            OPT12230
900   DO 910 I=1,NO                                                      OPT12240
      DO 910 J=1,MH                                                      OPT12250
      PRO(I,J)=0.00                                                      OPT12260
      DO 910 K=1,NC                                                      OPT12270
910   PRO(I,J)=PRO(I,J)+RC(I,K)*FBGE(J,K)                                OPT12280
      DO 920 I=1,MH                                                      OPT12290
      DO 920 J=1,MH                                                      OPT12300
      CQ(I,J)=0.00                                                       OPT12310
      DO 920 K=1,NC                                                      OPT12320
920   CQ(I,J)=CQ(I,J)-FBGE(I,K)*PRO(K,J)                                 OPT12330
930   CONTINUE                                                           OPT12340
C------------------THE RMS STATE AND CONTROL RESPONSES----------------OPT12350
      IR=IR+1                                                            OPT12360
      GO TO (1090,1090,940,940), IR                                      OPT12370
940   DO 950 I=1,NS                                                      OPT12380
      DO 950 J=1,NG                                                      OPT12390
      X(I,J)=0.0                                                         OPT12400
      DO 950 K=1,NG                                                      OPT12410
950   X(I,J)=X(I,J)+GAM(I,K)*Q(K,J)                                      OPT12420
      DO 970 I=1,NS                                                      OPT12430
      DO 970 J=I,NS                                                      OPT12440
      SUM=0.0                                                            OPT12450
      DO 960 K=1,NG                                                      OPT12460
960   SUM=SUM-X(I,K)*GAM(J,K)                                            OPT12470
      PRO(I,J)=SUM+CQ(I,J)                                               OPT12480
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      PRO(J,I)=PRC(I,J)                                                 OPT12490
      CQ(I,J)=SUM                                                       OPT12500
      CQ(J,I)=SUM                                                       OPT12510
      W21(I,J)=GM(I,J)                                                  OPT12520
  970 W21(J,I)=GM(J,I)                                                  OPT12530
      CALL MINV (NSQ,W21,NS,DDD,D1,D2)                                  OPT12540
      CALL SCOV (NS,GM,W21,CR,CI,NS,GM,W21,CR,CI,PRC,GN)                OPT12550
      WRITE (6,1670)                                                    OPT12560
      CALL RAPRNT (MH,MH,MH,5,GN,4,'(5(1X,1PD13.6))')                   OPT12570
      WRITE (6,1680)                                                    OPT12580
      DO 980 I=1,MH                                                     OPT12590
  980 X(I,I)=DSQRT(GN(I,I))                                             OPT12600
      WRITE (6,1690) (X(I,I),I=1,MH)                                    OPT12610
      IF (IQ.EQ.0) GO TO 1260                                           OPT12620
      DO 1000 I=1,NC                                                    OPT12630
      DO 1000 J=1,NS                                                    OPT12640
      SUM=0.0                                                           OPT12650
      DO 990 K=1,NS                                                     OPT12660
  990 SUM=SUM+FBGC(I,K)*GN(K,J)                                         OPT12670
 1000 X(I,J)=SUM                                                        OPT12680
      DO 1020 I=1,NS                                                    OPT12690
      DO 1020 J=1,NS                                                    OPT12700
      SUM=0.0                                                           OPT12710
      IF (NC.EQ.0) GO TO 1020                                           OPT12720
      DO 1010 K=1,NC                                                    OPT12730
 1010 SUM=SUM+G(I,K)*X(K,J)                                             OPT12740
 1020 PRO(I,J)=CQ(I,J)+SUM                                              OPT12750
      CALL SCOV (NS,SC,W11,CWR,CWI,NS,GM,W21,CR,CI,PRO,BA)              OPT12760
      IF (NC.EQ.0) GO TO 1040                                           OPT12770
      DO 1030 I=1,NC                                                    OPT12780
      DO 1030 J=1,NS                                                    OPT12790
      W21(I,J)=0.0                                                      OPT12800
      DO 1030 K=1,NS                                                    OPT12810
 1030 W21(I,J)=W21(I,J)+FBGC(I,K)*BA(J,K)                               OPT12820
 1040 DO 1060 I=1,NS                                                    OPT12830
      DO 1060 J=1,NS                                                    OPT12840
      SUM=0.0                                                           OPT12850
      IF (NC.EQ.0) GO TO 1060                                           OPT12860
      DO 1050 K=1,NC                                                    OPT12870
 1050 SUM=SUM+G(I,K)*W21(K,J)                                           OPT12880
 1060 PRO(I,J)=SUM                                                      OPT12890
      DO 1070 I=1,NS                                                    OPT12900
      DO 1070 J=I,NS                                                    OPT12910
      PRO(I,J)=PRC(I,J)+CQ(I,J)+PRO(J,I)                                OPT12920
 1070 PRC(J,I)=PRC(I,J)                                                 OPT12930
      CALL SCOV (NS,SC,W11,CWR,CWI,NS,SC,W11,CWR,CWI,PRO,CQ)            OPT12940
      DO 1080 I=1,NS                                                    OPT12950
      DO 1080 J=I,NS                                                    OPT12960
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```
      GM(I,J)=CQ(I,J)-BA(I,J)-BA(J,I)+GN(I,J)                                  OPT12970
1080  GM(J,I)=GM(I,J)                                                          OPT12980
      GO TO 1100                                                               OPT12990
1090  CALL SCOV (NS,SC,W11,CWR,CWI,NS,SC,W11,CWR,CWI,CQ,GM)                    OPT13000
1100  IF (NC.EQ.0) GO TO 1150                                                  OPT13010
      DO 1120 I=1,NS                                                           OPT13020
      DO 1120 J=1,NC                                                           OPT13030
      PRO(I,J)=0.00                                                            OPT13040
      DO 1110 K=1,NS                                                           OPT13050
1110  PRO(I,J)=PRO(I,J)+GM(I,K)*FBGC(J,K)                                      OPT13060
1120  CONTINUE                                                                 OPT13070
      DO 1140 I=1,NC                                                           OPT13080
      DO 1140 J=1,NC                                                           OPT13090
      SC(I,J)=0.00                                                             OPT13100
      DO 1130 K=1,NS                                                           OPT13110
1130  SC(I,J)=SC(I,J)+FBGC(I,K)*PRO(K,J)                                       OPT13120
1140  CONTINUE                                                                 OPT13130
1150  IF (IREG .EQ. 0) GO TO 1170                                              OPT13140
      DO 1160 I=1,NS                                                           OPT13150
      DO 1160 J=1,NS                                                           OPT13160
1160  CQ(I,J)=GM(I,J)                                                          OPT13170
      GO TO 1190                                                               OPT13180
1170  WRITE (6,1700)                                                           OPT13190
      CALL RAPRNT (MH,MH,MH,5,GM,4,'(5(1X,1PD13.6))')                          OPT13200
      IF (IR.GT.2) GO TO 1190                                                  OPT13210
      DO 1180 I=1,MH                                                           OPT13220
      DO 1180 J=1,MH                                                           OPT13230
1180  CQ(I,J)=GN(I,J)+GM(I,J)                                                  OPT13240
1190  CONTINUE                                                                 OPT13250
      WRITE (6,1710)                                                           OPT13260
      CALL RAPRNT (MH,MH,MH,5,CQ,4,'(5(1X,1PD13.6))')                          OPT13270
      IF (NC.EQ.0) GO TO 1210                                                  OPT13280
      WRITE (6,1720)                                                           OPT13290
      DO 1200 I=1,NC                                                           OPT13300
1200  WRITE (6,1730) (SC(I,J),J=1,NC)                                          OPT13310
1210  DO 1220 I=1,NS                                                           OPT13320
1220  CQ(I,I)=DSQRT(CQ(I,I))                                                   OPT13330
      IF (NC.EQ.0) GO TO 1240                                                  OPT13340
      DO 1230 I=1,NC                                                           OPT13350
1230  SC(I,I)=DSQRT(SC(I,I))                                                   OPT13360
1240  WRITE (6,1740)                                                           OPT13370
      DO 1250 I=1,NS                                                           OPT13380
      IF (I.LE.NC) WRITE (6,1750) CQ(I,I),SC(I,I)                              OPT13390
      IF (I.GT.NC) WRITE (6,1750) CQ(I,I)                                      OPT13400
1250  CONTINUE                                                                 OPT13410
1260  IF (ITF3 .EQ. 0) GO TO 1290                                              OPT13420
C-------FORM COMPENSATOR FROM MEAS TO INPUT AND COMPUTE TF----------          OPT13430
      DO 1280 I=1,NS                                                           OPT13440
```

```
      DO 1280 J=1,NS                                                    OPT13450
      SUM=0.DO                                                          OPT13460
      DO 1270 K=1,NC                                                    OPT13470
1270  SUM=SUM+FBGE(I,K)*HO(K,J)                                         OPT13480
1280  CQ(I,J)=ACL(I,J)-SUM                                              OPT13490
      WRITE (6,1760)                                                    OPT13500
      ITFX=3                                                            OPT13510
      IZERO=0                                                           OPT13520
      CALL TF (NS,NS,NSQ,CQ,AA,NC,FBGE,BM,NC,FBGC,CM,IZERC,D,BB,CC,CP,  OPT13530
     1WR,WI,CWR,CWI,SC,JCF,RES,D1,D2,DDD,EPS,ITF3,ITFX)                 OPT13540
1290  CONTINUE                                                          OPT13550
C----------COMPUTE PSD FUNCTIONS OF THE CONTROLLED SYSTEM---------------OPT13560
      IF (IPSD .EC. 0) GO TO 1310                                       OPT13570
      IF (IYU .LT. 3) GO TC 1300                                        OPT13580
      CALL PSDCAL (M,NS,RM,X,NC,GW,GV,FBGC,NO,HY,HU,HC,FBGE,NG,         OPT13590
     1 GAM,ACL,BA,WR,WI,D1,D2,JCF,RES,Q,RC,BB,CC,1  ,IPSD,INORM)        OPT13600
      CALL PSDCAL (M,NS,RM,X,NC,GW,GV,FBGC,NC,HY,HY,HC,FBGE,NG,         OPT13610
     1 GAM,ACL,BA,WR,WI,D1,D2,JCF,RES,Q,RC,BB,CC,2  ,IPSD,INORM)        OPT13620
      GO TO 1310                                                        OPT13630
1300  CALL PSDCAL (M,NS,RM,X,NC,GW,GV,FBGC,NO,HY,HU,HC,FBGE,NG,         OPT13640
     1 GAM,ACL,BA,WR,WI,D1,D2,JCF,RES,Q,RC,BB,CC,IYU,IPSD,INORM)        OPT13650
1310  IF (ISS .EC. 0) RETURN                                            OPT13660
      IF (NC .NE. 0) GO TO 1330                                         OPT13670
      DC 1320 I=1,NS                                                    OPT13680
      DO 1320 J=1,NS                                                    OPT13690
1320  ACL(I,J)=BA(I,J)                                                  OPT13700
1330  CONTINUE                                                          OPT13710
      CALL MINV (NSQ,ACL,NS,DDD,D1,D2)                                  OPT13720
      CALL READW (NG,WR)                                                OPT13730
      WRITE (6,1770) (WR(I),I=1,NG)                                     OPT13740
      WRITE (6,1780)                                                    OPT13750
      DO 1340 I=1,NS                                                    OPT13760
      WI(I)=0.0                                                         OPT13770
      DO 1340 J=1,NG                                                    OPT13780
1340  WI(I)=WI(I)+GAM(I,J)*WR(J)                                        OPT13790
      DO 1360 I=1,NS                                                    OPT13800
      CR(I)=0.0                                                         OPT13810
      DO 1350 J=1,NS                                                    OPT13820
1350  CR(I)=CR(I)-ACL(I,J)*WI(J)                                        OPT13830
1360  WRITE (6,1790) CR(I)                                              OPT13840
      DO 1370 I=1,NC                                                    OPT13850
      CI(I)=0.0                                                         OPT13860
      DO 1370 J=1,NS                                                    OPT13870
1370  CI(I)=CI(I)+FBGC(I,J)*CR(J)                                       OPT13880
      WRITE (6,1790) (CI(I),I=1,NC)                                     OPT13890
      RETURN                                                            OPT13900
C-----------------------------------------------------------------------OPT13910
C670  FORMAT (2X,1P6D14.6,/,2X,6D14.6)                                  OPT13920
```

```
 1380  FORMAT (//,5X,45HOPEN LOOP DYNAMICS MATRIX.....F..,//)OPT13930
 1390  FORMAT (10(2X,0PD11.4))                                OPT13940
 1400  FORMAT (//,5X,45HTHE CONTROL DISTRIBUTION MATRIX.....G..,//)OPT13950
 1410  FORMAT (//,5X,45HTHE CONTROL COST MATRIX.....B..,//)OPT13960
 1420  FORMAT (//,5X,45HPROCESS NOISE DISTRIBUTION MATRIX.....GAMMA..,//)OPT13970
 1430  FORMAT (//,5X,45HPOWER SPECTRAL DENSITY - PROCESS NOISE....Q..,//)OPT13980
 1440  FORMAT (//,5X,45HMEASUREMENT SCALING MATRIX.....H..,//)OPT13990
 1450  FORMAT (//,5X,45HPOWER SPECTRAL DENSITY-MEASUREMENT NOISE..R..,//)OPT14000
 1460  FORMAT (//,5X,45HOUTPUT COST MATRIX.....A..,//)OPT14010
 1470  FORMAT (//,5X,45HMEASUREMENT FEEDTHROUGH MATRIX.....D..,//)OPT14020
 1480  FORMAT (//,25X,28H....DESTABILIZATION CASE....,//,10X,39HTHE FOLLOOPT14030
     1WING VALUES WILL BE ADDED DOWN,/,10X,49HTHE DIAGONAL OF THE "F" MAOPT14040
     2TRIX TO DESTABILIZE IT.,/,10X,41HOPTIMAL GAINS FOR THE DESTABILIZEOPT14050
     3D SYSTEM,/,10X,39HARE THEN USED AS FIXED SUBOPTIMAL GAINS,/,10X,28OPT14060
     4HFOR THE SYSTEM CALCULATIONS.,//)                      OPT14070
 1490  FORMAT (///43H PROGRAM TERMINATING DUE TO UNSTABLE SYSTEM)  OPT14080
 1500  FORMAT (//,5X,31HOPEN LOOP TRANSFER FUNCTIONS...)      OPT14090
 1510  FORMAT (//,5X,32H EULER-LAGRANGE SYSTEM MATRIX...,//)  OPT14100
 1520  FORMAT (//,5X,43HEIGENVALUES AND EIGENVECTORS OF THE 2N X 2N,/,5X,OPT14110
     145HEULER-LAGRANGE SYSTEM AFTER HQR2.....,//)           OPT14120
 1530  FORMAT (1X,1P2D13.6)                                   OPT14130
 1540  FORMAT (1X)                                            OPT14140
 1550  FORMAT (//,5X,41HEIGENSYSTEM OF OPTIMAL REGULATOR.....,//)  OPT14150
 1560  FORMAT (//,5X,41HEIGENSYSTEM OF OPTIMAL ESTIMATOR.....,//)  OPT14160
 1570  FORMAT (//,5X,39H EIGENVECTORS FROM RGAIN PRIOR TO CNORM,//)  OPT14170
 1580  FORMAT (//,2X,57HTHE OPTIMAL FEEDBACK GAIN CONTROL MATRIX...C=BINVOPT14180
     1*GT*S...,//)                                          OPT14190
 1590  FORMAT (10(2X,1PD11.4))                                OPT14200
 1600  FORMAT (//,5X,45HTHE CLOSED LOOP DYNAMICS MATRIX .....F-G*C...,//)OPT14210
 1610  FORMAT (///,60H   PROGRAM TERMINATING DUE TO UNSTABLE CLOSED LOOP OPT14220
     1    SYSTEM)                                           OPT14230
 1620  FORMAT (//,2X,'NOISE TRANSFER FUNCTIONS THROUGH THE CLOSED-LOOP SYOPT14240
     1STEM...',//)                                          OPT14250
 1630  FORMAT (//,5X,45HFILTER STEADY STATE GAINS.....K...,//)OPT14260
 1640  FORMAT (1X,2X,1P6D14.6)                                OPT14270
 1650  FORMAT (//,5X,45HTHE CLOSED LOOP FILTER DYNAMICS MATRIX IS....,//)OPT14280
 1660  FORMAT (////,43H PROGRAM TERMINATING DUE TO UNSTABLE FILTER)  OPT14290
 1670  FORMAT (//,5X,45HTHE COVARIANCE OF THE ESTIMATION ERROR....P...,//)OPT14300
 1680  FORMAT (//,5X,45HRMS VALUES OF THE ESTIMATION ERROR.....,//)OPT14310
 1690  FORMAT ((5(1X,1PD13.6)))                               OPT14320
 1700  FORMAT (//,5X,45HTHE COVARIANCE OF THE ESTIMATE.....XHAT..,//)OPT14330
 1710  FORMAT (//,5X,45HTHE STATE COVARIANCE MATRIX.....X=XHAT + P...,//)OPT14340
 1720  FORMAT (//,5X,45HTHE CONTROL COVARIANCE.....U=C*XHAT*CT...,//)OPT14350
 1730  FORMAT (1P6D14.6)                                      OPT14360
 1740  FORMAT (//,2X,18HSTATE RMS RESPONSE,20X,20HCONTROL RMS RESPONSE,/)OPT14370
 1750  FORMAT (1X,1PD15.7,25X,D15.7)                          OPT14380
 1760  FORMAT (//,5X,50HCOMPENSATOR TRANSFER FUNCTIONS FROM MEAS. TO INPUOPT14390
     1T,/,5X,52H.....U/Z = -C*(SI-F+G*C+K*H)INV*K...,//)OPT14400
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1770  FORMAT (//,5X,46HSTEADY DISTURBANCE VECTOR.....W..,//OPT14410
     1,10(1X,1PD12.4/))                                    OPT14420
1780  FORMAT (//,5X,45HSTEADY STATE VALUES OF STATE VAR. ARE.......,//)OPT14430
1790  FORMAT (//,5X,47HSTEADY STATE CONTROL IS .....,/OPT14440
     1/10(1X,1PD12.4/))                                    OPT14450
1800  FORMAT (//,5X,49HENTER THE MAGNITUDE OF THE DESTABILIZATION VECTOROPT14460
     1,/,8X,47HTO BE ADDED DOWN THE DIAGONAL OF THE "F"-MATRIX,/,8X,18HTOPT14470
     2O DESTABILIZE IT.,//)                                OPT14480
C-------------------------------------------GRGRAPH DATA----------OPT14490
2000  FORMAT(5X,2D30.14)                                    OPT14500
C-----------------------------------------------------------------OPT14510
      END                                                   OPT14520
C=================================================================OPT14530
      SUBROUTINE RAPRNT (NMAX,M,N,L,A,IDIM,FMT)             OPT14540
      REAL*8 A(NMAX,N)                                      OPT14550
      DIMENSION FMT(IDIM)                                   OPT14560
      NU=L                                                  OPT14570
      DO 20 NL=1,N,L                                        OPT14580
      IF (NU.GT.N) NU=N                                     OPT14590
      DO 10 I=1,M                                           OPT14600
10    WRITE (6,FMT) (A(I,J),J=NL,NU)                        OPT14610
      WRITE (6,30)                                          OPT14620
20    NU=NU+L                                               OPT14630
      RETURN                                                OPT14640
30    FORMAT (1X)                                           OPT14650
      END                                                   OPT14660
C=================================================================OPT14670
      SUBROUTINE RGAIN (M,NS,NC,NOB,WR,WI,VF,GN,W11,TCB,W21,LT,C,CI,CT,MOPT14680
     1HS,MT)                                                OPT14690
      IMPLICIT REAL*8 (A-H,O-Z)                             OPT14700
      DIMENSION WR(M),WI(M),VF(M,M),GN(NS,NS)               OPT14710
      DIMENSION W11(NS,NS),TCB(M,M),W21(NS,NS),LT(NS),MT(NS)OPT14720
      DIMENSION C(NS),CI(NS),CT(NS,NS)                      OPT14730
      K=1                                                   OPT14740
      KP=1                                                  OPT14750
      KN=1                                                  OPT14760
      NRZEV=0                                               OPT14770
      NCPZEV=0                                              OPT14780
10    IF (K.GT.M) GO TO 210                                 OPT14790
C-----------------------------------------------------------------OPT14800
C CHECK FOR EIGVAL AT OR NEAR J-OMEGA AXIS TO INCLUDE IN E-L EIGSYS OPT14810
C  TURN FIRST ONE POSITIVE AND SECOND ONE NEGATIVE            OPT14820
C-----------------------------------------------------------------OPT14830
      EIGVR=DABS(WR(K))                                     OPT14840
      IF (EIGVR.GE.1.D-10) GO TO 60                         OPT14850
      IF (WI(K)) 40,20,40                                   OPT14860
20    NRZEV=NRZEV+1                                         OPT14870
      IF (NRZEV.GT.1) GO TO 30                              OPT14880
```

```
      WR(K)=EIGVR                                                       OPT14890
      GO TO 80                                                          OPT14900
30    WR(K)=-EIGVR                                                      OPT14910
      WRITE (6,290)                                                     OPT14920
      GO TO 150                                                         OPT14930
40    NCPZEV=NCPZEV+1                                                   OPT14940
      IF (NCPZEV.GT.1) GO TO 50                                         OPT14950
      WR(K)=EIGVR                                                       OPT14960
      WR(K+1)=EIGVR                                                     OPT14970
      GO TO 110                                                         OPT14980
50    WR(K)=-EIGVR                                                      OPT14990
      WR(K+1)=-EIGVR                                                    OPT15000
      WRITE (6,300)                                                     OPT15010
      GO TO 180                                                         OPT15020
60    IF (WR(K)) 140,70,70                                              OPT15030
70    IF (WI(K)) 110,80,110                                             OPT15040
C-----------------EIGENVECTOR FOR REAL EIGENVALUE,POSITIVE--------------OPT15050
80    IF (NOB.EQ.0) GO TO 100                                           OPT15060
      DO 90 J=1,N                                                       OPT15070
90    TCB(J,KP)=VF(J,K)                                                 OPT15080
100   KP=KP+1                                                           OPT15090
      K=K+1                                                             OPT15100
      GO TO 10                                                          OPT15110
C-----------EIGENVECTOR FOR COMPLEX EIGENVALUE,POSITIVE REAL PART-------OPT15120
110   IF (NOB.EQ.0) GO TO 130                                           OPT15130
      DO 120 J=1,N                                                      OPT15140
      FR=VF(J,K)                                                        OPT15150
      FI=-VF(J,K+1)                                                     OPT15160
      TCB(J,KP)=FR+FI                                                   OPT15170
120   TCB(J,KP+1)=FR-FI                                                 OPT15180
130   KP=KP+2                                                           OPT15190
      K=K+2                                                             OPT15200
      GO TO 10                                                          OPT15210
140   IF (WI(K)) 180,150,180                                            OPT15220
C-------------EIGENVECTOR FOR REAL EIGENVALUE,NEGATIVE REAL PART--------OPT15230
150   C(KN)=WR(K)                                                       OPT15240
      CI(KN)=WI(K)                                                      OPT15250
      IF (NOB.NE.0) GO TO 170                                           OPT15260
      KNS=KN+NS                                                         OPT15270
      DO 160 J=1,N                                                      OPT15280
160   TCB(J,KNS)=VF(J,K)                                                OPT15290
170   KN=KN+1                                                           OPT15300
      K=K+1                                                             OPT15310
      GO TO 10                                                          OPT15320
C------------EIGENVECTOR FOR COMPLEX EIGENVALUE,NEGATIVE REAL PART------OPT15330
180   RR=WR(K)                                                          OPT15340
      RI=WI(K)                                                          OPT15350
      C(KN)=RR                                                          OPT15360
```

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      C(KN+1)=RR                                                        OPT15370
      CI(KN)=RI                                                         OPT15380
      CI(KN+1)=-RI                                                      OPT15390
      IF (NOB.NE.0) GO TO 200                                           OPT15400
      KNS=KN+NS                                                         OPT15410
      DO 190 J=1,M                                                      OPT15420
      FR=VF(J,K)                                                        OPT15430
      FI=-VF(J,K+1)                                                     OPT15440
      TCB(J,KNS)=FR+FI                                                  OPT15450
  190 TCB(J,KNS+1)=FR-FI                                                OPT15460
  200 KN=KN+2                                                           OPT15470
      K=K+2                                                             OPT15480
      GO TO 10                                                          OPT15490
  210 CONTINUE                                                          OPT15500
      IF (NOB.NE.0) GO TO 240                                           OPT15510
C-----------------------FORMATION OF W11-----------------------------OPT15520
      DO 220 I=1,NS                                                     OPT15530
      DO 220 J=1,NS                                                     OPT15540
      W11(I,J)=TCB(I,J+NS)                                              OPT15550
  220 CT(I,J)=W11(I,J)                                                  OPT15560
C-----------------------FORMATION OF W21-----------------------------OPT15570
      DO 230 I=1,NS                                                     OPT15580
      DO 230 J=1,NS                                                     OPT15590
  230 W21(I,J)=TCB(I+NS,J+NS)                                           OPT15600
  240 IF (NOB.EQ.0) GO TO 260                                           OPT15610
      DO 250 I=1,NS                                                     OPT15620
      DO 250 J=1,NS                                                     OPT15630
      W21(I,J)=-TCB(I,J)                                                OPT15640
  250 W11(I,J)=TCB(I+NS,J)                                              OPT15650
  260 CONTINUE                                                          OPT15660
C-----------------------INVERT W11-----------------------------------OPT15670
      NSQ=NS*NS                                                         OPT15680
      CALL MINV (NSQ,W11,NS,DETC,LT,MT)                                 OPT15690
C--------------------CALCULATE THE RGAIN MATRIX----------------------OPT15700
      DO 270 IL=1,NS                                                    OPT15710
      DO 270 JL=1,NS                                                    OPT15720
      GN(IL,JL)=0.D0                                                    OPT15730
      DO 270 KL=1,NS                                                    OPT15740
  270 GN(IL,JL)=GN(IL,JL)+W21(IL,KL)*W11(KL,JL)                         OPT15750
      IF (NOB.EQ.0) RETURN                                              OPT15760
      DO 280 I=1,NS                                                     OPT15770
      DO 280 J=1,NS                                                     OPT15780
  280 CT(I,J)=W11(J,I)                                                  OPT15790
      RETURN                                                            OPT15800
C-----------------------------------------------------------------------OPT15810
  290 FORMAT (1X,51H EULER-LAGRANGE EQUATIONS HAVE A REAL EIGENVALUE AT,OPT15820
     1 14H OR NEAR ZERO./)                                              OPT15830
  300 FORMAT (1X,49H EULER-LAGRANGE EQUATIONS HAVE A COMPLEX PAIR OF ,40OPT15840
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     1HEIGENVALUES AT OR NEAR THE J-OMEGA AXIS.)                              OPT15850
      END                                                                     OPT15860
C=====================================================================OPT15870
      SUBROUTINE MINV (NSQ,A,N,D,L,M)                                         OPT15880
      IMPLICIT REAL*8 (A-H,O-Z)                                               OPT15890
      DIMENSION A(NSQ),L(N),M(N)                                              OPT15900
      DOUBLE PRECISION A,D,BIGA,HOLD                                          OPT15910
      NM=N*N                                                                  OPT15920
      D=1.0D0                                                                 OPT15930
      NK=-N                                                                   OPT15940
      DO 180 K=1,N                                                            OPT15950
      NK=NK+N                                                                 OPT15960
      L(K)=K                                                                  OPT15970
      M(K)=K                                                                  OPT15980
      KK=NK+K                                                                 OPT15990
      BIGA=A(KK)                                                              OPT16000
      DO 20 J=K,N                                                             OPT16010
      IZ=N*(J-1)                                                              OPT16020
      DO 20 I=K,N                                                             OPT16030
      IJ=IZ+I                                                                 OPT16040
      IF (DABS(BIGA)-DABS(A(IJ))) 10,20,20                                    OPT16050
10    BIGA=A(IJ)                                                              OPT16060
      L(K)=I                                                                  OPT16070
      M(K)=J                                                                  OPT16080
20    CONTINUE                                                                OPT16090
C-----------------------INTERCHANGE ROWS----------------------------OPT16100
      J=L(K)                                                                  OPT16110
      IF (J-K) 50,50,30                                                       OPT16120
30    KI=K-N                                                                  OPT16130
      DO 40 I=1,N                                                             OPT16140
      KI=KI+N                                                                 OPT16150
      HOLD=-A(KI)                                                             OPT16160
      JI=KI-K+J                                                               OPT16170
      A(KI)=A(JI)                                                             OPT16180
40    A(JI)=HOLD                                                              OPT16190
C----------------------INTERCHANGE COLUMNS--------------------------OPT16200
50    I=M(K)                                                                  OPT16210
      IF (I-K) 80,80,60                                                       OPT16220
60    JP=N*(I-1)                                                              OPT16230
      DO 70 J=1,N                                                             OPT16240
      JK=NK+J                                                                 OPT16250
      JI=JP+J                                                                 OPT16260
      HOLD=-A(JK)                                                             OPT16270
      A(JK)=A(JI)                                                             OPT16280
70    A(JI)=HOLD                                                              OPT16290
C---------------------DIVIDE COLUMN BY MINUS PIVOT-----------------OPT16300
C-----------------(VALUE OF PIVOT ELEMENT IS CONTAINED IN BIGA)--------OPT16310
80    IF (BIGA) 100,90,100                                                    OPT16320
```

```
 90     D=0.0D0                                                          OPT16330
        RETURN                                                           OPT16340
100     DO 120 I=1,N                                                    OPT16350
        IF (I-K) 110,120,110                                            OPT16360
110     IK=NK+I                                                         OPT16370
        A(IK)=A(IK)/(-BIGA)                                             OPT16380
120     CONTINUE                                                        OPT16390
C------------------------------REDUCE MATRIX------------------------------OPT16400
        DO 150 I=1,N                                                    OPT16410
        IK=NK+I                                                         OPT16420
        HOLD=A(IK)                                                      OPT16430
        IJ=I-N                                                          OPT16440
        DO 150 J=1,N                                                    OPT16450
        IJ=IJ+N                                                         OPT16460
        IF (I-K) 130,150,130                                            OPT16470
130     IF (J-K) 140,150,140                                            OPT16480
140     KJ=IJ-I+K                                                       OPT16490
        A(IJ)=HOLD*A(KJ)+A(IJ)                                          OPT16500
150     CONTINUE                                                        OPT16510
C-----------------------------DIVIDE ROW BY PIVOT-------------------------OPT16520
        KJ=K-N                                                          OPT16530
        DO 170 J=1,N                                                    OPT16540
        KJ=KJ+N                                                         OPT16550
        IF (J-K) 160,170,160                                            OPT16560
160     A(KJ)=A(KJ)/BIGA                                                OPT16570
170     CONTINUE                                                        OPT16580
C----------------------------PRODUCT OF PIVOTS----------------------------OPT16590
        D=D*BIGA                                                        OPT16600
C---------------------REPLACE PIVOT BY RECIPROCAL-------------------------OPT16610
        A(KK)=(1.0D0)/BIGA                                              OPT16620
180     CONTINUE                                                        OPT16630
C-------------------------FINAL ROW AND COLUMN INTERCHANGE----------------OPT16640
        K=N                                                             OPT16650
190     K=(K-1)                                                         OPT16660
        IF (K) 260,260,200                                              OPT16670
200     I=L(K)                                                          OPT16680
        IF (I-K) 230,230,210                                            OPT16690
210     JQ=N*(K-1)                                                      OPT16700
        JR=N*(I-1)                                                      OPT16710
        DO 220 J=1,N                                                    OPT16720
        JK=JQ+J                                                         OPT16730
        HOLD=A(JK)                                                      OPT16740
        JI=JR+J                                                         OPT16750
        A(JK)=-A(JI)                                                    OPT16760
220     A(JI)=HOLD                                                      OPT16770
230     J=M(K)                                                          OPT16780
        IF (J-K) 190,190,240                                            OPT16790
240     KI=K-N                                                          OPT16800
```

```
      DO 250 I=1,N                                                          OPT16810
      KI=KI+N                                                               OPT16820
      HOLD=A(KI)                                                            OPT16830
      JI=KI-K+J                                                             OPT16840
      A(KI)=-A(JI)                                                          OPT16850
250   A(JI)=HOLD                                                            OPT16860
      GO TO 190                                                             OPT16870
260   K=0                                                                   OPT16880
      RETURN                                                                OPT16890
      END                                                                   OPT16900
C=====================================================================OPT16910
      SUBROUTINE SCOV (NL,NL,WLI,VL1,VL2,NR,WR,WRI,VR1,VR2,Q,X)             OPT16920
      REAL*8 VL1(NL),VL2(NL),WL(NL,NL),WLI(NL,NL),X(NL,NR),Q(NL,NR),        OPT16930
     1   VR1(NR),VR2(NR),WR(NR,NR),WRI(NR,NR)                              OPT16940
      REAL*8 A,B,C,D,K1,K2,K3,K4                                            OPT16950
10    DO 20 I=1,NL                                                          OPT16960
      DO 20 J=1,NR                                                          OPT16970
      X(I,J)=0.                                                             OPT16980
      DO 20 II=1,NL                                                         OPT16990
20    X(I,J)=X(I,J)+WLI(I,II)*Q(II,J)                                       OPT17000
      DO 40 I=1,NL                                                          OPT17010
      DO 40 J=1,NR                                                          OPT17020
      Q(I,J)=0.                                                             OPT17030
      DO 30 JJ=1,NR                                                         OPT17040
30    Q(I,J)=Q(I,J)+X(I,JJ)*WRI(J,JJ)                                       OPT17050
40    CONTINUE                                                              OPT17060
      I=1                                                                   OPT17070
50    IF (VL2(I)) 60,110,60                                                 OPT17080
60    J=1                                                                   OPT17090
70    IF (VR2(J)) 80,90,80                                                  OPT17100
80    A=VL1(I)+VR1(J)                                                       OPT17110
      B=-2.*VL2(I)*VR2(J)                                                   OPT17120
      C=A**2+VL2(I)**2+VR2(J)**2                                            OPT17130
      D=C**2-B**2                                                           OPT17140
      K1=A*C/D                                                              OPT17150
      K2=-(VR2(J)*C+VL2(I)*B)/D                                             OPT17160
      K3=-(VR2(J)*B+VL2(I)*C)/D                                             OPT17170
      K4=-A*B/D                                                             OPT17180
      I1=I+1                                                                OPT17190
      J1=J+1                                                                OPT17200
      X(I,J)=+K1*Q(I,J)+K2*Q(I,J1)+K3*Q(I1,J)+K4*Q(I1,J1)                   OPT17210
      X(I,J1)=-K2*Q(I,J)+K1*Q(I,J1)-K4*Q(I1,J)+K3*Q(I1,J1)                  OPT17220
      X(I1,J)=-K3*Q(I,J)-K4*Q(I,J1)+K1*Q(I1,J)+K2*Q(I1,J1)                  OPT17230
      X(I1,J1)=+K4*Q(I,J)-K3*Q(I,J1)-K2*Q(I1,J)+K1*Q(I1,J1)                 OPT17240
      J=J+2                                                                 OPT17250
      GO TO 100                                                             OPT17260
90    A=VR1(J)+VL1(I)                                                       OPT17270
      B=A**2+VL2(I)**2                                                      OPT17280
```

```
      K1=A/B                                                                OPT17290
      K2=VL2(I)/B                                                           OPT17300
      X(I,J)=K1*Q(I,J)-K2*Q(I+1,J)                                          OPT17310
      X(I+1,J)=K2*Q(I,J)+K1*Q(I+1,J)                                        OPT17320
      J=J+1                                                                 OPT17330
100   IF (J.LE.NR) GO TO 70                                                 OPT17340
      I=I+2                                                                 OPT17350
      GO TO 160                                                             OPT17360
110   J=1                                                                   OPT17370
120   IF (VR2(J)) 130,140,130                                               OPT17380
130   A=VR1(J)+VL1(I)                                                       OPT17390
      B=A**2+VR2(J)**2                                                      OPT17400
      K1=A/B                                                                OPT17410
      K2=VR2(J)/B                                                           OPT17420
      X(I,J)=K1*Q(I,J)-K2*Q(I,J+1)                                          OPT17430
      X(I,J+1)=K2*Q(I,J)+K1*Q(I,J+1)                                        OPT17440
      J=J+2                                                                 OPT17450
      GO TO 150                                                             OPT17460
140   X(I,J)=Q(I,J)/(VR1(J)+VL1(I))                                         OPT17470
      J=J+1                                                                 OPT17480
150   IF (J.LE.NR) GO TO 120                                                OPT17490
      I=I+1                                                                 OPT17500
160   IF (I.LE.NL) GO TO 50                                                 OPT17510
      DO 170 I=1,NL                                                         OPT17520
      DO 170 J=1,NR                                                         OPT17530
      Q(I,J)=0.                                                             OPT17540
      DO 170 II=1,NL                                                        OPT17550
170   Q(I,J)=Q(I,J)+WL(I,II)*X(II,J)                                        OPT17560
      DO 190 I=1,NL                                                         OPT17570
      DO 190 J=1,NR                                                         OPT17580
      X(I,J)=0.                                                             OPT17590
      DO 180 JJ=1,NR                                                        OPT17600
180   X(I,J)=X(I,J)+Q(I,JJ)*WR(J,JJ)                                        OPT17610
190   CONTINUE                                                              OPT17620
      RETURN                                                                OPT17630
      END                                                                   OPT17640
C=====================================================================OPT17650
      SUBROUTINE MODE (WNORM,G,GNORM,NS,N1,N2,ICON)                         OPT17660
C                                                                          =OPT17670
C  WNORM  TRANSFORMATION MATRIX U OR U-INV                                 =OPT17680
C  NS      NO. OF STATE                                                    =OPT17690
C  NC      NO.  OF INPUTS OR OUTPUTS                                       =OPT17700
C  ICON  CONTROL FLAG TO INDICATE WHICH TRANSFORMATION                     =OPT17710
C          0 =  MODAL G                                                    =OPT17720
C          1 =  MODAL GAMMA                                                =OPT17730
C          2 =  MODAL H                                                    =OPT17740
C          3 =  MODAL C                                                    =OPT17750
C          4 =  MODAL K                                                    =OPT17760
```

```
C          5 =  CONTROL EIGENVECTOR MATRIX                                    =OPT17770
C          6 =  MEASUREMENT EIGENVECTOR MATRIX                                =OPT17780
C=============================================================================OPT17790
      IMPLICIT REAL*8(A-H,C-Z)                                                 OPT17800
      DIMENSION WNORM(NS,NS),G(N1,N2),GNORM(N1,N2)                             OPT17810
      DO 10 I=1,N1                                                             OPT17820
      DO 10 J=1,N2                                                             OPT17830
10    GNORM(I,J)=C.                                                            OPT17840
      IPOINT=ICON+1                                                            OPT17850
      GO TO (20,20,90,90,20,90,90), IPCINT                                     OPT17860
20    DO 30 J=1,N2                                                             OPT17870
      DO 30 I=1,NS                                                             OPT17880
      DO 30 K=1,NS                                                             OPT17890
30    GNORM(I,J)=GNORM(I,J)+WNORM(I,K)*G(K,J)                                  OPT17900
      GO TO (40,70,90,90,80), IPCINT                                           OPT17910
40    WRITE (6,170)                                                            OPT17920
50    DO 60 I=1,NS                                                             OPT17930
60    WRITE (6,230) (GNORM(I,J),J=1,N2)                                        OPT17940
      RETURN                                                                   OPT17950
70    WRITE (6,180)                                                            OPT17960
      GO TO 50                                                                 OPT17970
80    WRITE (6,240)                                                            OPT17980
      GO TO 50                                                                 OPT17990
90    DO 100 J=1,NS                                                            OPT18000
      DO 100 I=1,N1                                                            OPT18010
      DO 100 K=1,NS                                                            OPT18020
100   GNORM(I,J)=GNORM(I,J)+G(I,K)*WNORM(K,J)                                  OPT18030
      GO TO (110,110,110,120,110,130,140), IPOINT                              OPT18040
110   WRITE (6,190)                                                            OPT18050
      GO TO 150                                                                OPT18060
120   WRITE (6,200)                                                            OPT18070
      GO TO 150                                                                OPT18080
130   WRITE (6,210)                                                            OPT18090
      GO TO 150                                                                OPT18100
140   WRITE (6,220)                                                            OPT18110
150   DO 160 I=1,N1                                                            OPT18120
160   WRITE (6,230) (GNORM(I,J),J=1,NS)                                        OPT18130
      RETURN                                                                   OPT18140
C-----------------------------------------------------------------------------OPT18150
170   FORMAT (//,5X,45HMODAL CONTROL DISTRIBUTION MATRIX.....TI*G..,//)OPT18160
180   FORMAT (//,5X,50HMODAL PROCESS NOISE DISTRIBUTION MATRIX...TI*GAM.OPT18170
     1.,//)                                                                    OPT18180
190   FORMAT (//,5X,45HMODAL MEASUREMENT SCALING MATRIX...H(BAR)*T..,//)OPT18190
200   FORMAT (//,5X,45HTHE MODAL CONTROL GAINS.................C*T..,//)OPT18200
210   FORMAT (//,5X,45HCONTROL EIGENVECTOR MATRIX..............C*M..,//)OPT18210
220   FORMAT (//,5X,45HMEASUREMENT EIGENVECTOR MATRIX.....H(BAR)*M..,//)OPT18220
230   FORMAT (1X,(2X,1P6D14.6))                                                OPT18230
240   FORMAT (//,5X,45HMODAL FILTER STEADY STATE GAINS........TI*K..,//)OPT18240
```

```
      END                                                                   OPT18250
C=====================================================================OPT18260
      SUBROUTINE CNORM (WZ,WY,VEC,NS,IWRITE,NSQ,DDD,D1,D2,WNORM,WNORMI,HOPT18270
     1O,CM,N1,N2)                                                          OPT18280
C                                                                          =OPT18290
CC          WZ(I)      REAL PART OF I-TH EIGENVALUE                       =OPT18300
CC                                                                         =OPT18310
CC          WY(I)      COMPLEX PART OF I-TH EIGENVALUE                    =OPT18320
CC                                                                         =OPT18330
CC          VEC        MATRIX OF RIGHT EIGENVECTORS STORED IN REAL FORM   =OPT18340
CC                       FROM HQR2                                         =OPT18350
CC          NS         NO. OF STATES                                      =OPT18360
CC                                                                         =OPT18370
CC          IWRITE     FLAG TO CONTROL FORMATS FOR DIFFERENT EIGENSYSTEMS=OPT18380
CC                                                                         =OPT18390
CC          WNORM      NORMALIZED MATRIX U OF RIGHT EIGENVECTORS STORED   =OPT18400
CC                       BY COLUMNS IN REAL FORM                           =OPT18410
CC          WNORMI     U-INVERSE 2*CONGUGATE OF LEFT EIGENVECTORS         =OPT18420
CC                       STORED BY ROW IN REAL FORM                        =OPT18430
C           NSQ,DDD,D1,D2 - ARGUMENTS PASSED TO MINV                       =OPT18440
C=====================================================================OPT18450
      IMPLICIT REAL*8 (A-H,O-Z)                                             OPT18460
      REAL*8 FIELD,COMMA,SEMCOL,RIGHT,FMT                                   OPT18470
      DIMENSION WZ(NS),WY(NS),VEC(NS,NS),WNORM(NS,NS),WNORMI(NS,NS),STOROPT18480
     1E(6),D1(NS),D2(NS),FMT(14),HO(N1,N2),CM(N1,N2)                        OPT18490
      DATA FIELD/5HE12.5/,COMMA/5H,',',/,SEMCOL/5H,':',/,RIGHT/1H)/,FMT/OPT18500
     16H(1X,1P,13*1H /,SEMEND/4H,':'/                                      OPT18510
C----------NORMALIZE COMPLEX EIGENVECTORS BY LARGEST ELEMENT-------------OPT18520
      KK=0                                                                  OPT18530
      LR=0                                                                  OPT18540
      LC=0                                                                  OPT18550
      DO 50 K=1,NS                                                          OPT18560
      IF (KK.EQ.1) GO TO 40                                                 OPT18570
      IF (DABS(WY(K)).LT.1.D-10) GO TO 50                                   OPT18580
      LC=LC+1                                                               OPT18590
      EMAX=0.DO                                                             OPT18600
      DO 20 I=1,NS                                                          OPT18610
      CMOD=VEC(I,K)**2+VEC(I,K+1)**2                                        OPT18620
      IF (CMOD-EMAX) 20,10,10                                               OPT18630
10    EMAX=CMOD                                                             OPT18640
      M=I                                                                   OPT18650
20    CONTINUE                                                              OPT18660
      VMR=VEC(M,K)                                                          OPT18670
      VMI=VEC(M,K+1)                                                        OPT18680
      DO 30 I=1,NS                                                          OPT18690
      VR=VEC(I,K)                                                           OPT18700
      VI=VEC(I,K+1)                                                         OPT18710
      VECRN=(VR*VMR+VI*VMI)/EMAX                                            OPT18720
```

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      VECIN=(-VR*VMI+VI*VMR)/EMAX                                       OPT18730
      WNORM(I,K)=VECRN                                                  OPT18740
      WNORM(I,K+1)=VECIN                                                OPT18750
30    CONTINUE                                                          OPT18760
      KK=1                                                              OPT18770
      GO TO 50                                                          OPT18780
40    KK=0                                                              OPT18790
50    CONTINUE                                                          OPT18800
C-----------NORMALIZE REAL EIGENVECTORS BY THE TOTAL LENGTH-----------OPT18810
      DO 80 K=1,NS                                                      OPT18820
      IF (DABS(WY(K)).GE.1.D-10) GO TO 80                               OPT18830
      LR=LR+1                                                           OPT18840
      REMOD=0.D0                                                        OPT18850
      DO 60 I=1,NS                                                      OPT18860
60    REMOD=VEC(I,K)**2+REMOD                                           OPT18870
      RMOD=DSQRT(REMOD)                                                 OPT18880
      DO 70 I=1,NS                                                      OPT18890
      RVEC=VEC(I,K)/RMOD                                                OPT18900
      WNORM(I,K)=RVEC                                                   OPT18910
70    CONTINUE                                                          OPT18920
80    CONTINUE                                                          OPT18930
      GO TO (90,100,110,120,130), IWRITE                                OPT18940
90    WRITE (6,320)                                                     OPT18950
      GO TO 140                                                         OPT18960
100   WRITE (6,330)                                                     OPT18970
      GO TO 140                                                         OPT18980
110   WRITE (6,340)                                                     OPT18990
      GO TO 140                                                         OPT19000
120   WRITE (6,350)                                                     OPT19010
      GO TO 140                                                         OPT19020
130   WRITE (6,360)                                                     OPT19030
140   KK=0                                                              OPT19040
      NPRTW=0                                                           OPT19050
      NFMTW=1                                                           OPT19060
      DO 180 I=1,NS                                                     OPT19070
      IF (KK.EQ.1) GO TO 170                                            OPT19080
      IF (DABS(WY(I)).GT.1.D-10) KK=1                                   OPT19090
C----PRINT OUT NO MORE THAN 6 WORDS, NOT SEPARATING COMPLEX EIGVAL------OPT19100
      IF (NPRTW.LT.5.OR.(NPRTW.EQ.5.AND.KK.EQ.0)) GO TO 150             OPT19110
      FMT(NFMTW+1)=RIGHT                                                OPT19120
      WRITE (6,FMT) (STORE(J),J=1,NPRTW)                                OPT19130
      NPRTW=0                                                           OPT19140
      NFMTW=1                                                           OPT19150
150   NPRTW=NPRTW+1                                                     OPT19160
      NFMTW=NFMTW+1                                                     OPT19170
      IF (KK.EQ.1) GO TO 160                                            OPT19180
      STORE(NPRTW)=WZ(I)                                                OPT19190
      FMT(NFMTW)=FIELD                                                  OPT19200
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      NFMTW=NFMTW+1                                                    OPT19210
      FMT(NFMTW)=SEMCOL                                                OPT19220
      GO TO 180                                                        OPT19230
160   STORE(NPRTW)=WZ(I)                                               OPT19240
      FMT(NFMTW)=FIELD                                                 OPT19250
      FMT(NFMTW+1)=COMMA                                               OPT19260
      STORE(NPRTW+1)=WY(I)                                             OPT19270
      FMT(NFMTW+2)=FIELD                                               OPT19280
      FMT(NFMTW+3)=SEMCOL                                              OPT19290
      NFMTW=NFMTW+3                                                    OPT19300
      NPRTW=NPRTW+1                                                    OPT19310
      GO TO 180                                                        OPT19320
170   KK=0                                                             OPT19330
180   CONTINUE                                                         OPT19340
      FMT(NFMTW)=SEMEND                                                OPT19350
      FMT(NFMTW+1)=RIGHT                                               OPT19360
      WRITE (6,FMT) (STORE(J),J=1,NPRTW)                               OPT19370
      IF (IWRITE.NE.1) GO TO 190                                       OPT19380
      WRITE (6,370)                                                    OPT19390
      GO TO 200                                                        OPT19400
190   WRITE (6,380)                                                    OPT19410
200   CALL RAPRNT (NS,NS,NS,6,WNORM,4,'(6(1X,1PD13.6))')               OPT19420
      GO TO (230,210,210,220,220), IWRITE                              OPT19430
210   CALL MODE (WNORM,HO,CM,NS,N1,N2,5)                               OPT19440
      GO TO 230                                                        OPT19450
220   CALL MODE (WNORM,HO,CM,NS,N1,N2,6)                               OPT19460
230   GO TO (240,250,260,270,280), IWRITE                              OPT19470
240   WRITE (6,390)                                                    OPT19480
      GO TO 290                                                        OPT19490
250   WRITE (6,400)                                                    OPT19500
      GO TO 290                                                        OPT19510
260   WRITE (6,410)                                                    OPT19520
      GO TO 290                                                        OPT19530
270   WRITE (6,420)                                                    OPT19540
      GO TO 290                                                        OPT19550
280   WRITE (6,430)                                                    OPT19560
C-----------------SAVE U-INVERSE OPEN LOOP IN WNORMI-----------------OPT19570
290   IF (IWRITE .GT. 1) GO TO 310                                     OPT19580
      DO 300 I=1,NS                                                    OPT19590
      DO 300 J=1,NS                                                    OPT19600
300   WNORMI(I,J)=WNORM(I,J)                                           OPT19610
      CALL MINV (NSQ,WNORMI,NS,DDD,D1,D2)                              OPT19620
      CALL RAPRNT (NS,NS,NS,6,WNORMI,4,'(6(1X,1PD13.6))')              OPT19630
      RETURN                                                           OPT19640
310   CALL MINV (NSQ,WNORM,NS,DDD,D1,D2)                               OPT19650
      CALL RAPRNT (NS,NS,NS,6,WNORM,4,'(6(1X,1PD13.6))')               OPT19660
      RETURN                                                           OPT19670
C-----------------------------------------------------------------------OPT19680
```

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  320   FORMAT (//5X,42HOPEN LOOP EIGENVALUES..........DET(SI-F)..,//)     OPT19690
  330   FORMAT (//5X,46HC-LOOP OPTIMAL REG. E-VALUES...DET(SI-F+G*C)..,//)OPT19700
  340   FORMAT (//5X,46HC-LOOP SUBOPT. REG. E-VALUES...DET(SI-F+G*C)..,//)OPT19710
  350   FORMAT (//5X,46HC-LOOP OPTIMAL EST. E-VALUES...DET(SI-F+K*H)..,//)OPT19720
  360   FORMAT (//5X,46HC-LOOP SUBOPT. EST. E-VALUES...DET(SI-F+K*H)..,//)OPT19730
  370   FORMAT (//5X,46HOPEN LOOP RIGHT EIGENVECTOR MATRIX.......T....,//)OPT19740
  380   FORMAT (//5X,46HC-LOOP RIGHT EIGENVECTOR MATRIX..........M.....,//)OPT19750
  390   FORMAT (//5X,46HOPEN LOOP LEFT EIGENVECTOR MATRIX.......T-INV..,//)OPT19760
  400   FORMAT (//5X,46HC-LOOP OPT. REG. LEFT E-VECTOR MATRIX..M-INV..,//)OPT19770
  410   FORMAT (//5X,46HC-LOOP SUBOPT-REG. LEFT E-VECTOR MATRIX..M-INV,//)OPT19780
  420   FORMAT (//5X,46HC-LOOP OPT. FILTER LEFT E-VECTOR MATRIX..M-INV,//)OPT19790
  430   FORMAT (//5X,51HC-LOOP SUBOPT. FILTER LEFT E-VECTOR MATRIX..M-INV.OPT19800
     1.,//)                                                               OPT19810
        END                                                               OPT19820
C=================================================================      OPT19830
        SUBROUTINE TF (N,NM,NSQ,A,AA,M,B,BM,L,C,CM,IFDFW,D,BB,CC,CP,      OPT19840
     1      EVR,EVI,PR,PI,SC,JCF,RES,D1,D2,DDD,EPS,ITF,ITFX)              OPT19850
        IMPLICIT REAL*8(A-H,O-Z)                                          OPT19860
        DIMENSION A(N,N),AA(N,N),B(N,M),BM(N,M),C(L,N),CM(L,N),D(L,M),BB(NOPT19870
     1),CC(N),CP(N),EVR(N),EVI(N),PR(N),PI(N),SC(N,N),JCF(N),RES(N),D1(NOPT19880
     2),D2(N)                                                             OPT19890
C--SAVE COMPUTATION ON OL AND CL SYS WITH MODAL WORK DONE IN CPTSYS-----OPT19900
        IF (ITFX .EQ. 1) GO TO 50                                         OPT19910
        IF (ITFX .EQ. 2) GO TO 10                                         OPT19920
        CALL POLES (N,NM,A,AA,M,B,L,C,PR,PI,D1,D2,JCF,SC)                 OPT19930
C---------------COMPUTE MODAL MATRICES FOR RESIDUES---------------------OPT19940
10      DO 20 I=1,N                                                       OPT19950
        DO 20 J=1,N                                                       OPT19960
20      AA(I,J)=SC(I,J)                                                   OPT19970
        DO 30 I=1,L                                                       OPT19980
        DO 30 J=1,N                                                       OPT19990
        CM(I,J)=0.DO                                                      OPT20000
        DO 30 K=1,N                                                       OPT20010
30      CM(I,J)=CM(I,J)+C(I,K)*AA(K,J)                                    OPT20020
        CALL MINV (NSQ,AA,N,DDD,D1,D2)                                    OPT20030
        DO 40 I=1,N                                                       OPT20040
        DO 40 J=1,M                                                       OPT20050
        BM(I,J)=0.DO                                                      OPT20060
        DO 40 K=1,N                                                       OPT20070
40      BM(I,J)=BM(I,J)+AA(I,K)*B(K,J)                                    OPT20080
50      CONTINUE                                                          OPT20090
        DO 60 I=1,N                                                       OPT20100
        DO 60 J=1,L                                                       OPT20110
        IF (ITF .NE. 3) CALL ZEROS (I,J,IFDFW,N,NM,A,AA,M,B,L,C,D,BB,CC,CPOPT20120
     1,EVR,EVI,D1,D2,EPS,ITFX)                                            OPT20130
        IF (ITF .NE. 2) CALL RESID (I,J,N,JCF,M,BM,L,CM,PR,PI,RES,BB,CC,1)OPT20140
60      CONTINUE                                                          OPT20150
        RETURN                                                            OPT20160
```

```
      END                                                                   OPT20170
C=====================================================================OPT20180
      SUBROUTINE POLES (N,NM,A,AA,M,B,L,C,EVR,EVI,D1,D2,JCF,SC)          OPT20190
      IMPLICIT REAL*8(A-H,C-Z)                                          OPT20200
      DIMENSION A(N,N),AA(N,N),B(N,M),C(L,N),EVR(N),EVI(N),D1(N),D2(N),JOPT20210
     1CF(N),SC(N,N)                                                     OPT20220
      DO 10 I=1,N                                                       OPT20230
      DO 10 J=1,N                                                       OPT20240
10    AA(I,J)=A(I,J)                                                    OPT20250
      CALL BALANC (NM,N,AA,LOW,IHIGH,D1)                                OPT20260
      CALL ORTHES (NM,N,LOW,IHIGH,AA,D2)                                OPT20270
      CALL ORTRAN (NM,N,LOW,IHIGH,AA,D2,SC)                             OPT20280
      CALL HQR2 (NM,N,LOW,IHIGH,AA,EVR,EVI,SC,IERR)                     OPT20290
      IF (IERR .NE. 0) GO TO 30                                         OPT20300
      CALL BALBAK (NM,N,LOW,IHIGH,D1,N,SC)                              OPT20310
      WRITE (6,40)                                                      OPT20320
      DO 20 I=1,N                                                       OPT20330
C-----------------------------------------------OPTGRCM DATA----------OPT20340
      WRITE (4,2000) EVR(I),EVI(I)                                      OPT20350
C-------------------------------------------------------------------OPT20360
20    WRITE (6,50) EVR(I),EVI(I)                                        OPT20370
      RETURN                                                            OPT20380
30    WRITE (5,60)                                                      OPT20390
      RETURN                                                            OPT20400
C-------------------------------------------------------------------OPT20410
40    FORMAT (///,28H TF DENOMINATOR EIGENVALUES:,/)                    OPT20420
50    FORMAT (/,2X,3H  (,F13.6,4H)+J(,F13.6,1H))                        OPT20430
60    FORMAT (35H FAILURE IN HQR2, CALCULATING POLES)                   OPT20440
C-----------------------------------------------OPTGRCM DATA----------OPT20450
2000  FORMAT(5X,2D30.14)                                                OPT20460
C-------------------------------------------------------------------OPT20470
      END                                                               OPT20480
C=====================================================================OPT20490
      SUBROUTINE ZEROS (K1,K2,IFDFW,N,NM,A,AA,M,B,L,C,D,BB,CC,CP,EVR,EVIOPT20500
     1,    D1,D2,EPS,ITFX)                                             OPT20510
      IMPLICIT REAL*8(A-H,C-Z)                                          OPT20520
      DIMENSION A(N,N),AA(N,N),B(N,M),C(L,N),D(L,M),BB(N),CC(N),CP(N),EVOPT20530
     1R(N),EVI(N),D1(N),D2(N)                                           OPT20540
      DOUBLE PRECISION SCL,DABS                                         OPT20550
C-----------------------------------OPGRAPH DATA ------------------OPT20560
      IF(ITFX.EQ.1) IFL = 10                                            OPT20570
      IF(ITFX.EQ.2) IFL = 1                                             OPT20580
      IF(ITFX.EQ.3) IFL = 4                                             OPT20590
C-------------------------------------------------------------------OPT20600
      DO 10 I=1,N                                                       OPT20610
      BB(I)=B(I,K1)                                                     OPT20620
      CC(I)=C(K2,I)                                                     OPT20630
      DO 10 J=1,N                                                       OPT20640
```

```
10      AA(I,J)=A(I,J)                                                  OPT20650
        WRITE (6,90) K1,K2                                              OPT20660
        IF (IFCFW .EQ. 0) GO TO 20                                      OPT20670
        H=D(K2,K1)                                                      OPT20680
        IF (DABS(H).LE.EPS) GO TO 20                                    OPT20690
        JJ=N                                                            OPT20700
        GO TO 50                                                        OPT20710
20      NN=N-1                                                          OPT20720
        DO 30 I=1,NN                                                    OPT20730
        H=SCL(N,BB,CC)                                                  OPT20740
        CALL CCOMP (N,NM,AA,CC,CP)                                      OPT20750
        IF (DABS(H).GT.EPS) GO TO 40                                    OPT20760
30      CONTINUE                                                        OPT20770
        H=SCL(N,BB,CC)                                                  OPT20780
        WRITE (6,100) H                                                 OPT20790
C-------------------------------------OPGRAPH DATA FOR "0" ORDER-------OPT20800
           KK=ITFX                                                      OPT20810
           WRITE (IFL,300) KK,K2,K1                                     OPT20820
           ORDER = 0.0                                                  OPT20830
           WRITE (IFL,301) ORDER,H                                      OPT20840
C-------------------------------------------------------------------OPT20850
        GO TO 70                                                        OPT20860
40      JJ=N-I                                                          OPT20870
50      WRITE (6,110) JJ,H                                              OPT20880
C-------------------------------------OPGRAPH DATA -------------------OPT20890
           KK=ITFX                                                      OPT20900
           WRITE (IFL,300) KK,K2,K1                                     OPT20910
           ORDER = FLOAT(JJ)                                            OPT20920
           WRITE (IFL,301) ORDER,H                                      OPT20930
C-------------------------------------------------------------------OPT20940
        CALL ACOMP (N,NM,AA,BB,CC,H)                                    OPT20950
        CALL BALANC (NM,N,AA,LOW,IHIGH,D1)                              OPT20960
        CALL ORTHES (NM,N,LOW,IHIGH,AA,D2)                              OPT20970
        CALL HQR (NM,N,LOW,IHIGH,AA,EVR,EVI,IERR)                       OPT20980
        IF (IERR .NE. 0) GO TO 80                                       OPT20990
        WRITE (6,120)                                                   OPT21000
        DO 60 I=1,N                                                     OPT21010
60      WRITE (6,130) EVR(I),EVI(I)                                     OPT21020
C-------------------------------------OPGRAPH DATA -------------------OPT21030
           WRITE (IFL,302) K2,K1                                        OPT21040
        DO 63 LL = 1,N                                                  OPT21050
63         WRITE (IFL,301) EVR(LL),EVI(LL)                              OPT21060
C-------------------------------------------------------------------OPT21070
70      RETURN                                                          OPT21080
80      WRITE (5,140)                                                   OPT21090
        RETURN                                                          OPT21100
C-------------------------------------------------------------------OPT21110
90      FORMAT (///,17H TF FOR INPUT NO.,I3,15H AND OUTPUT NO.,I3,1H:)  OPT21120
```

```
100   FORMAT (//,5X,27HNO FINITE ZEROS.  TF GAIN =,E12.4)                    OPT21130
110   FORMAT (/,3X,20HORDER OF NUMERATOR =,I3,9X,9HTF GAIN =,E12.4)          OPT21140
120   FORMAT (/,3X,57HNUMERATOR EIGENVALUES (INCLUDING EXTRANEOUS ZERO VOPT21150
     1ALUES):)                                                              OPT21160
130   FORMAT (/,4X,1H(,F13.6,4H)+J(,F13.6,1H))                              OPT21170
140   FORMAT (52H FAILURE IN HQR CALCULATING TRANSFER FUNCTION ZEROES)       OPT21180
C-----------------------------------------------OPGRAPH DATA-----------OPT21190
300   FORMAT(5X,3I5)                                                        OPT21200
301   FORMAT(5X,2D30.14)                                                    OPT21210
302   FORMAT(5X,2I5)                                                        OPT21220
C-----------------------------------------------------------------------OPT21230
      END                                                                   OPT21240
C=======================================================================OPT21250
      SUBROUTINE ACOMP (N,NM,A,B,C,H)                                       OPT21260
      REAL*8 A,B,C,H                                                        OPT21270
      DIMENSION A(NM,N),B(N),C(N)                                           OPT21280
      DO 10 I=1,N                                                           OPT21290
      DO 10 J=1,N                                                           OPT21300
10    A(I,J)=A(I,J)-B(I)*C(J)/H                                             OPT21310
      RETURN                                                                OPT21320
      END                                                                   OPT21330
C=======================================================================OPT21340
      SUBROUTINE CCOMP (N,NM,A,C,CC)                                        OPT21350
      REAL*8 A,C,CC                                                         OPT21360
      DIMENSION A(NM,N),C(N),CC(N)                                          OPT21370
      DO 10 I=1,N                                                           OPT21380
      CC(I)=0.                                                              OPT21390
      DO 10 J=1,N                                                           OPT21400
10    CC(I)=CC(I)+C(J)*A(J,I)                                               OPT21410
      DO 20 I=1,N                                                           OPT21420
20    C(I)=CC(I)                                                            OPT21430
      RETURN                                                                OPT21440
      END                                                                   OPT21450
C=======================================================================OPT21460
      FUNCTION SCL (N,B,C)                                                  OPT21470
      REAL*8 B,C,SCL                                                        OPT21480
      DIMENSION B(N),C(N)                                                   OPT21490
      SCL=0.                                                                OPT21500
      DO 10 I=1,N                                                           OPT21510
10    SCL=SCL+C(I)*B(I)                                                     OPT21520
      RETURN                                                                OPT21530
      END                                                                   OPT21540
C=======================================================================OPT21550
      SUBROUTINE RESID (K1,K2,N,JCF,M,BM,L,CM,PR,PI,RES,BB,CC,IPT)          OPT21560
      IMPLICIT REAL*8(A-H,O-Z)                                              OPT21570
      DIMENSION JCF(N),BM(N,M),CM(L,N),PR(N),PI(N),RES(N),BB(N),CC(N),PROPT21580
     1T(4)                                                                  OPT21590
      DATA SN/8H*SIN(B*T/,R1/8H       */,R2/8HEXP(A*T)/,ED/1H)/             OPT21600
```

```
      DATA ZERO/0.D0/,T1/4H*T**/,BLANK/8H        /,CS/8H*COS(B*T/        OPT21610
C-------------TEMPORARY MOD TILL JCF IS CALCULATED---------------------OPT21620
      DO 10 I=1,N                                                       OPT21630
10    JCF(I)=0                                                          OPT21640
C-----------------------TEMPORARY MOD-------------------------------OPT21650
      IF (IPT .EQ. 1) WRITE (6,170)                                     OPT21660
      DO 20 I=1,N                                                       OPT21670
      BB(I)=BM(I,K1)                                                    OPT21680
20    CC(I)=CM(K2,I)                                                    OPT21690
C--------------------LOOP THROUGH THE POLES---------------------------OPT21700
      I=0                                                               OPT21710
30    I=I+1                                                             OPT21720
      IF (I .GT. N) GO TO 160                                           OPT21730
      IF (JCF(I) .EQ. 1) GO TO 60                                       OPT21740
      IF (DABS(PI(I)) .LT. 1.D-10) GO TO 50                             OPT21750
C---------COMPUTE SIMPLE COMPLEX POLE RESIDUES AND PRINT BOTH----------OPT21760
      RES(I)=CC(I)*BB(I)+CC(I+1)*BB(I+1)                                OPT21770
      RES(I+1)=CC(I)*BB(I+1)-CC(I+1)*BB(I)                              OPT21780
      IF (IPT .EQ. 0) GO TO 40                                          OPT21790
      PRT(1)=BLANK                                                      OPT21800
      PRT(2)=R2                                                         OPT21810
      IF (PI(I) .EQ. 0.D0) PRT(2)=BLANK                                 OPT21820
      PRT(3)=CS                                                         OPT21830
      PRT(4)=ED                                                         OPT21840
      WRITE (6,180) PR(I),PI(I),RES(I),(PRT(J),J=1,4)                   OPT21850
      I=I+1                                                             OPT21860
      PRT(3)=SN                                                         OPT21870
      WRITE (6,180) PR(I),PI(I),RES(I),(PRT(J),J=1,4)                   OPT21880
      GO TO 30                                                          OPT21890
40    I=I+1                                                             OPT21900
      GO TO 30                                                          OPT21910
50    CONTINUE                                                          OPT21920
C----------------COMPUTE SIMPLE REAL POLE RESIDUE---------------------OPT21930
      RES(I)=CC(I)*BB(I)                                                OPT21940
      IF (IPT .EQ. 0) GO TO 30                                          OPT21950
      PRT(1)=R1                                                         OPT21960
      PRT(2)=R2                                                         OPT21970
      PRT(3)=BLANK                                                      OPT21980
      PRT(4)=BLANK                                                      OPT21990
      WRITE (6,180) PR(I),PI(I),RES(I),(PRT(J),J=1,4)                   OPT22000
      GO TO 30                                                          OPT22010
C----------LOOK AHEAD TO DETERMINE SIZE OF THE JORDAN BLOCK-------------OPT22020
60    K=1                                                               OPT22030
      KT=N-I                                                            OPT22040
      DO 70 J=I,KT                                                      OPT22050
      IF (JCF(J) .EQ. 0) GO TO 80                                       OPT22060
70    K=K+1                                                             OPT22070
80    CONTINUE                                                          OPT22080
```

```
      IF (DABS(PI(I)) .LT. 1.D-10) GO TO 110                            OPT22090
C---------COMPUTE REPEATED COMPLEX POLE AND PRINT OUT ALL FOUR----------OPT22100
      K=1                                                               OPT22110
      RES(I)=CC(I)*BB(I)+CC(I+1)*BB(I+1)+CC(I+2)*BB(I+2)+CC(I+3)*BB(I+3)OPT22120
      RES(I+1)=CC(I)*BB(I+1)-CC(I+1)*BB(I)+CC(I+2)*BB(I+3)-CC(I+3)*BB(I+OPT22130
     12)                                                                OPT22140
      RES(I+2)=CC(I)*BB(I+2)+CC(I+1)*BB(I+2)                            OPT22150
      RES(I+3)=CC(I)*BB(I+3)-CC(I+1)*BB(I+2)                            OPT22160
      IF (IPT .EQ. 0) GO TO 100                                         OPT22170
      PRT(1)=R1                                                         OPT22180
      PRT(2)=R2                                                         OPT22190
      IF (DABS(PR(I)) .GT. 1.D-10) GO TO 90                             OPT22200
      PRT(1)=BLANK                                                      OPT22210
      PRT(2)=BLANK                                                      OPT22220
90    PRT(3)=CS                                                         OPT22230
      PRT(4)=ED                                                         OPT22240
      WRITE (6,180) PR(I),PI(I),RES(I),(PRT(J),J=1,4)                   OPT22250
      PRT(3)=SN                                                         OPT22260
      I=I+1                                                             OPT22270
      WRITE (6,180) PR(I),PI(I),RES(I),(PRT(J),J=1,4)                   OPT22280
      PRT(1)=T1                                                         OPT22290
      PRT(2)=R2                                                         OPT22300
      IF (DABS(PR(I)) .LT. 1.D-10) PRT(2)=BLANK                         OPT22310
      PRT(3)=CS                                                         OPT22320
      I=I+1                                                             OPT22330
      WRITE (6,190) PR(I),PI(I),RES(I),PRT(1),K,(PRT(J),J=2,4)          OPT22340
      PRT(3)=SN                                                         OPT22350
      I=I+1                                                             OPT22360
      WRITE (6,190) PR(I),PI(I),RES(I),PRT(1),K,(PRT(J),J=2,4)          OPT22370
      GO TO 30                                                          OPT22380
100   I=I+3                                                             OPT22390
      GO TO 30                                                          OPT22400
C----COMPUTE REPEATED REAL POLE RESIDUE AND PRINT OUT ALL K OF THEM-----OPT22410
110   CONTINUE                                                          OPT22420
      KT=I+K-1                                                          OPT22430
      NN=0                                                              OPT22440
      DO 130 J=I,KT                                                     OPT22450
      NN=NN+1                                                           OPT22460
      RES(J)=ZERO                                                       OPT22470
      DO 120 JJ=J,KT                                                    OPT22480
120   RES(J)=RES(J)+BB(JJ)*CC(JJ-NN+1)                                  OPT22490
130   CONTINUE                                                          OPT22500
      IF (IPT .EQ. 0) GO TO 150                                         OPT22510
      NN=0                                                              OPT22520
      PRT(1)=T1                                                         OPT22530
      PRT(2)=R2                                                         OPT22540
      PRT(3)=BLANK                                                      OPT22550
      PRT(4)=BLANK                                                      OPT22560
```

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      DO 140 J=I,KT                                                    OPT22570
      WRITE (6,190) PR(J),PI(J),RES(J),PRT(1),NN,(PRT(JJ),JJ=2,4)      OPT22580
140   NN=NN+1                                                          OPT22590
      GO TO 30                                                         OPT22600
150   I=KT                                                             OPT22610
      GO TO 30                                                         OPT22620
160   CONTINUE                                                         OPT22630
      RETURN                                                           OPT22640
C-----------------------------------------------------------------------OPT22650
170   FORMAT (//,3X,22HRESIDUES AT THE POLES:/,T16,9HF O L E S,T41,15HR OPT22660
     1E S I D U E S,/,T9,7HREAL(A),T26,7HIMAG(B))                      OPT22670
180   FORMAT (/,4X,1H(,F13.6,4H)+J(,F13.6,1H),4X,1H(,F13.6,1H),3A8,A1)  OPT22680
190   FORMAT (/,4X,1H(,F13.6,4H)+J(,F13.6,1H),4X,1H(,F13.6,1H),A4,I2,2X,OPT22690
     12A8,A1)                                                          OPT22700
      END                                                              OPT22710
C=======================================================================OPT22720
      SUBROUTINE BALANC (NM,N,A,LOW,IGH,SCALE)                         OPT22730
      INTEGER I,J,K,L,M,N,JJ,NM,IGH,LOW,IEXC                           OPT22740
      REAL*8 A(NM,N),SCALE(N)                                          OPT22750
      REAL*8 C,F,G,R,S,B2,RADIX                                        OPT22760
      REAL*8 DABS                                                      OPT22770
      LOGICAL NOCONV                                                   OPT22780
      DATA RADIX/Z4210000CCCC000000/                                   OPT22790
C-----------------------------------------------------------------------OPT22800
      B2=RADIX*RADIX                                                   OPT22810
      K=1                                                              OPT22820
      L=N                                                              OPT22830
      GO TO 60                                                         OPT22840
C-------------IN-LINE PROCEDURE FOR ROW AND COLUMN EXCHANGE-------------OPT22850
10    SCALE(M)=J                                                       OPT22860
      IF (J .EQ. M) GO TO 40                                           OPT22870
      DO 20 I=1,L                                                      OPT22880
      F=A(I,J)                                                         OPT22890
      A(I,J)=A(I,M)                                                    OPT22900
      A(I,M)=F                                                         OPT22910
20    CONTINUE                                                         OPT22920
      DO 30 I=K,N                                                      OPT22930
      F=A(J,I)                                                         OPT22940
      A(J,I)=A(M,I)                                                    OPT22950
      A(M,I)=F                                                         OPT22960
30    CONTINUE                                                         OPT22970
40    GO TO (50,90), IEXC                                              OPT22980
C-----SEARCH FOR ROWS ISOLATING AN EIGENVALUE AND PUSH THEM DOWN--------OPT22990
50    IF (L .EQ. 1) GO TO 230                                          OPT23000
      L=L-1                                                            OPT23010
60    DO 80 JJ=1,L                                                     OPT23020
      J=L+1-JJ                                                         OPT23030
      DO 70 I=1,L                                                      OPT23040
```

```
      IF (I .EQ. J) GO TO 70                                            OPT23050
      IF (A(J,I) .NE. 0.0D0) GO TO 80                                   OPT23060
 70   CONTINUE                                                          OPT23070
      M=L                                                               OPT23080
      IEXC=1                                                            OPT23090
      GO TO 10                                                          OPT23100
 80   CONTINUE                                                          OPT23110
      GO TO 100                                                         OPT23120
C-------SEARCH FOR COLUMNS ISOLATING AN EIGENVALUE AND PUSH THEM LEFT---OPT23130
 90   K=K+1                                                             OPT23140
100   DO 120 J=K,L                                                      OPT23150
      DO 110 I=K,L                                                      OPT23160
      IF (I .EQ. J) GO TO 110                                           OPT23170
      IF (A(I,J) .NE. 0.0D0) GO TO 120                                  OPT23180
110   CONTINUE                                                          OPT23190
      M=K                                                               OPT23200
      IEXC=2                                                            OPT23210
      GO TO 10                                                          OPT23220
120   CONTINUE                                                          OPT23230
C----------------NOW BALANCE THE SUBMATRIX IN ROWS K TO L--------------OPT23240
      DO 130 I=K,L                                                      OPT23250
130   SCALE(I)=1.0D0                                                    OPT23260
C----------------ITERATIVE LOOP FOR NORM REDUCTION---------------------OPT23270
140   NOCONV=.FALSE.                                                    OPT23280
      DO 220 I=K,L                                                      OPT23290
      C=0.0D0                                                           OPT23300
      R=0.0D0                                                           OPT23310
      DO 150 J=K,L                                                      OPT23320
      IF (J .EQ. I) GO TO 150                                           OPT23330
      C=C+DABS(A(J,I))                                                  OPT23340
      R=R+DABS(A(I,J))                                                  OPT23350
150   CONTINUE                                                          OPT23360
C----------------GUARD AGAINST ZERO C OR R DUE TO UNDERFLOW------------OPT23370
      IF (C .EQ. 0.0D0 .OR. R .EQ. 0.0D0) GO TO 220                     OPT23380
      G=R/RADIX                                                         OPT23390
      F=1.0D0                                                           OPT23400
      S=C+R                                                             OPT23410
160   IF (C .GE. G) GO TO 170                                           OPT23420
      F=F*RADIX                                                         OPT23430
      C=C*B2                                                            OPT23440
      GO TO 160                                                         OPT23450
170   G=R*RADIX                                                         OPT23460
180   IF (C .LT. G) GO TO 190                                           OPT23470
      F=F/RADIX                                                         OPT23480
      C=C/B2                                                            OPT23490
      GO TO 180                                                         OPT23500
C----------------------------NOW BALANCE-------------------------------OPT23510
190   IF ((C + R) / F .GE. 0.95D0 * S) GO TO 220                        OPT23520
```

```
      G=1.0D0/F                                                          OPT23530
      SCALE(I)=SCALE(I)*F                                                OPT23540
      NOCONV=.TRUE.                                                      OPT23550
      DO 200 J=K,N                                                       OPT23560
  200 A(I,J)=A(I,J)*G                                                    OPT23570
      DO 210 J=1,L                                                       OPT23580
  210 A(J,I)=A(J,I)*F                                                    OPT23590
  220 CONTINUE                                                           OPT23600
      IF (NOCONV) GO TO 140                                              OPT23610
  230 LOW=K                                                              OPT23620
      IGH=L                                                              OPT23630
      RETURN                                                             OPT23640
      END                                                                OPT23650
C=====================================================================OPT23660
      SUBROUTINE ORTHES (NM,N,LOW,IGH,A,ORT)                             OPT23670
      INTEGER I,J,M,N,II,JJ,LA,MP,NM,IGH,KP1,LOW                         OPT23680
      REAL*8 A(NM,N),ORT(IGH)                                            OPT23690
      REAL*8 F,G,H,SCALE                                                 OPT23700
      REAL*8 DSQRT,DABS,DSIGN                                            OPT23710
      LA=IGH-1                                                           OPT23720
      KP1=LOW+1                                                          OPT23730
      IF (LA .LT. KP1) GO TO 100                                         OPT23740
      DO 90 M=KP1,LA                                                     OPT23750
      H=0.0D0                                                            OPT23760
      ORT(M)=0.0D0                                                       OPT23770
      SCALE=0.0D0                                                        OPT23780
C----------------SCALE COLUMN (ALGOL TOL THEN NOT NEEDED)--------------OPT23790
      DO 10 I=M,IGH                                                      OPT23800
   10 SCALE=SCALE+DABS(A(I,M-1))                                         OPT23810
      IF (SCALE .EQ. 0.0D0) GO TO 90                                     OPT23820
      MP=M+IGH                                                           OPT23830
      DO 20 II=M,IGH                                                     OPT23840
      I=MP-II                                                            OPT23850
      ORT(I)=A(I,M-1)/SCALE                                              OPT23860
      H=H+ORT(I)*ORT(I)                                                  OPT23870
   20 CONTINUE                                                           OPT23880
      G=-DSIGN(DSQRT(H),ORT(M))                                          OPT23890
      H=H-ORT(M)*G                                                       OPT23900
      ORT(M)=ORT(M)-G                                                    OPT23910
C-----------------------FORM (I-(U*UT)/H) * A-------------------------OPT23920
      DO 50 J=M,N                                                        OPT23930
      F=0.0D0                                                            OPT23940
      DO 30 II=M,IGH                                                     OPT23950
      I=MP-II                                                            OPT23960
      F=F+ORT(I)*A(I,J)                                                  OPT23970
   30 CONTINUE                                                           OPT23980
      F=F/H                                                              OPT23990
      DO 40 I=M,IGH                                                      OPT24000
```

```
   40     A(I,J)=A(I,J)-F*ORT(I)                                          OPT24010
   50     CONTINUE                                                        OPT24020
C---------------------FORM (I-(U*UT)/H)*A*(I-(U*UT)/H)--------------------OPT24030
          DO 80 I=1,IGH                                                   OPT24040
          F=0.0D0                                                         OPT24050
          DO 60 JJ=M,IGH                                                  OPT24060
          J=MP-JJ                                                         OPT24070
          F=F+ORT(J)*A(I,J)                                               OPT24080
   60     CONTINUE                                                        OPT24090
          F=F/H                                                           OPT24100
          DO 70 J=M,IGH                                                   OPT24110
   70     A(I,J)=A(I,J)-F*ORT(J)                                          OPT24120
   80     CONTINUE                                                        OPT24130
          ORT(M)=SCALE*ORT(M)                                             OPT24140
          A(M,M-1)=SCALE*G                                                OPT24150
   90     CONTINUE                                                        OPT24160
  100     RETURN                                                          OPT24170
          END                                                             OPT24180
C=======================================================================OPT24190
          SUBROUTINE ORTRAN (NM,N,LOW,IGH,A,ORT,Z)                        OPT24200
          INTEGER I,J,N,KL,MM,MP,NM,IGH,LOW,MP1                           OPT24210
          REAL*8 A(NM,IGH),ORT(IGH),Z(NM,N)                               OPT24220
          REAL*8 G                                                        OPT24230
C-----------------INITIALIZE Z TO IDENTITY MATRIX----------------------OPT24240
          DO 20 I=1,N                                                     OPT24250
          DO 10 J=1,N                                                     OPT24260
   10     Z(I,J)=0.0D0                                                    OPT24270
          Z(I,I)=1.0D0                                                    OPT24280
   20     CONTINUE                                                        OPT24290
          KL=IGH-LOW-1                                                    OPT24300
          IF (KL .LT. 1) GO TO 80                                         OPT24310
          DO 70 MM=1,KL                                                   OPT24320
          MP=IGH-MM                                                       OPT24330
          IF (A(MP,MP-1) .EQ. 0.0D0) GO TO 70                             OPT24340
          MP1=MP+1                                                        OPT24350
          DO 30 I=MP1,IGH                                                 OPT24360
   30     ORT(I)=A(I,MP-1)                                                OPT24370
          DO 60 J=MP,IGH                                                  OPT24380
          G=0.0D0                                                         OPT24390
          DO 40 I=MP,IGH                                                  OPT24400
   40     G=G+ORT(I)*Z(I,J)                                               OPT24410
C-----------------DIVISOR BELOW IS NEGATIVE OF H FORMED IN ORTHES.-------OPT24420
C-----------------DOUBLE DIVISION AVOIDS POSSIBLE UNDERFLOW--------------OPT24430
          G=(G / ORT(MP))/A(MP,MP-1)                                      OPT24440
          DO 50 I=MP,IGH                                                  OPT24450
   50     Z(I,J)=Z(I,J)+G*ORT(I)                                          OPT24460
   60     CONTINUE                                                        OPT24470
   70     CONTINUE                                                        OPT24480
```

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8C     RETURN                                                                 OPT24490
       END                                                                    OPT24500
C=============================================================================OPT24510
       SUBROUTINE HQR2 (NM,N,LOW,IGH,H,WR,WI,Z,IERR)                          OPT24520
       INTEGER I,J,K,L,M,N,EN,II,JJ,LL,MM,NA,NM,NN,IGH,ITS,LOW,MP2,ENM2,IOPT24530
      1EPR                                                                    OPT24540
       REAL*8 H(NM,N),WR(N),WI(N),Z(NM,N)                                     OPT24550
       REAL*8 P,Q,R,S,T,W,X,Y,RA,SA,VI,VR,ZZ,NORM,MACHEP                      OPT24560
       REAL*8 DSQRT,DABS,DSIGN                                                OPT24570
       INTEGER MIN0                                                           OPT24580
       LOGICAL NOTLAS                                                         OPT24590
       COMPLEX *16Z3                                                          OPT24600
       COMPLEX *16DCMPLX                                                      OPT24610
       REAL*8 DREAL,DIMAG                                                     OPT24620
C----------STATEMENT FUNCTIONS ENABLE EXTRACTION OF REAL AND IMAGINARY--OPT24630
C----------PARTS OF DOUBLE PRECISION COMPLEX NUMBERS--------------------OPT24640
       DREAL(Z3)=Z3                                                           OPT24650
       DIMAG(Z3)=(0.0D0,-1.0D0)*Z3                                            OPT24660
       DATA MACHEP/Z3410000000000000/                                         OPT24670
       IERR=0                                                                 OPT24680
       NORM=0.0D0                                                             OPT24690
       K=1                                                                    OPT24700
C-------STORE ROOTS ISOLATED BY BALANC AND COMPUTE MATRIX NORM----------OPT24710
       DO 20 I=1,N                                                            OPT24720
       DO 10 J=K,N                                                            OPT24730
10     NORM=NORM+DABS(H(I,J))                                                 OPT24740
       K=I                                                                    OPT24750
       IF (I .GE. LOW .AND. I .LE. IGH) GO TO 20                              OPT24760
       WR(I)=H(I,I)                                                           OPT24770
       WI(I)=0.0D0                                                            OPT24780
20     CONTINUE                                                               OPT24790
       EN=IGH                                                                 OPT24800
       T=0.0D0                                                                OPT24810
C---------------SEARCH FOR NEXT EIGENVALUES----------------------------OPT24820
30     IF (EN .LT. LOW) GO TO 290                                             OPT24830
       ITS=0                                                                  OPT24840
       NA=EN-1                                                                OPT24850
       ENM2=NA-1                                                              OPT24860
C---------------LOOK FOR SINGLE SMALL SUB-DIAGONAL ELEMENT-------------OPT24870
40     DO 50 LL=LOW,EN                                                        OPT24880
       L=EN+LOW-LL                                                            OPT24890
       IF (L .EQ. LOW) GO TO 60                                               OPT24900
       S=DABS(H(L-1,L-1))+DABS(H(L,L))                                        OPT24910
       IF (S .EQ. 0.0D0) S=NORM                                               OPT24920
       IF (DABS(H(L,L-1)) .LE. MACHEP * S) GO TO 60                           OPT24930
50     CONTINUE                                                               OPT24940
C-----------------------------FORM SHIFT-------------------------------OPT24950
60     X=H(EN,EN)                                                             OPT24960
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```
      IF (L .EQ. EN) GO TO 220                                          OPT24970
      Y=H(NA,NA)                                                        OPT24980
      W=H(EN,NA)*H(NA,EN)                                               OPT24990
      IF (L .EQ. NA) GO TO 230                                          OPT25000
      IF (ITS .EQ. 30) GO TO 500                                        OPT25010
      IF (ITS .NE. 10 .AND. ITS .NE. 20) GO TO 80                       OPT25020
C--------------------FORM EXCEPTIONAL SHIFT---------------------------OPT25030
      T=T+X                                                             OPT25040
      DO 70 I=LOW,EN                                                    OPT25050
70    H(I,I)=H(I,I)-X                                                   OPT25060
      S=DABS(H(EN,NA))+DABS(H(NA,ENM2))                                 OPT25070
      X=0.75D0*S                                                        OPT25080
      Y=X                                                               OPT25090
      W=-0.4375D0*S*S                                                   OPT25100
80    ITS=ITS+1                                                         OPT25110
C---------LOOK FOR TWO CONSECUTIVE SMALL SUB-DIAGONAL ELEMENTS.---------OPT25120
      DO 90 MM=L,ENM2                                                   OPT25130
      M=ENM2+L-MM                                                       OPT25140
      ZZ=H(M,M)                                                         OPT25150
      R=X-ZZ                                                            OPT25160
      S=Y-ZZ                                                            OPT25170
      P=(R * S - W)/H(M+1,M)+H(M,M+1)                                   OPT25180
      Q=H(M+1,M+1)-ZZ-R-S                                               OPT25190
      R=H(M+2,M+1)                                                      OPT25200
      S=DABS(P)+DABS(Q)+DABS(R)                                         OPT25210
      P=P/S                                                             OPT25220
      Q=Q/S                                                             OPT25230
      R=R/S                                                             OPT25240
      IF (M .EQ. L) GO TO 100                                           OPT25250
      IF (DABS(H(M,M-1)) * (DABS(Q) + DABS(R)) .LE. MACHEP * DABS(P)    OPT25260
     1 * (DABS(H(M-1,M-1)) + DABS(ZZ) + DABS(H(M+1,M+1)))) GO TO 100    OPT25270
90    CONTINUE                                                          OPT25280
100   MP2=M+2                                                           OPT25290
      DO 110 I=MP2,EN                                                   OPT25300
      H(I,I-2)=0.0D0                                                    OPT25310
      IF (I .EQ. MP2) GO TO 110                                         OPT25320
      H(I,I-3)=0.0D0                                                    OPT25330
110   CONTINUE                                                          OPT25340
C--------DOUBLE QR STEP INVOLVING ROWS L TO EN AND COLUMNS M TO EN------OPT25350
      DO 210 K=M,NA                                                     OPT25360
      NOTLAS=K.NE.NA                                                    OPT25370
      IF (K .EQ. M) GO TO 120                                           OPT25380
      P=H(K,K-1)                                                        OPT25390
      Q=H(K+1,K-1)                                                      OPT25400
      R=0.0D0                                                           OPT25410
      IF (NOTLAS) R=H(K+2,K-1)                                          OPT25420
      X=DABS(P)+DABS(Q)+DABS(R)                                         OPT25430
      IF (X .EQ. 0.0D0) GO TO 210                                       OPT25440
```

```
      P=P/X                                                              OPT25450
      Q=Q/X                                                              OPT25460
      R=R/X                                                              OPT25470
120   S=DSIGN(DSQRT(P*P+Q*Q+R*R),P)                                      OPT25480
      IF (K .EQ. M) GO TO 130                                            OPT25490
      H(K,K-1)=-S*X                                                      OPT25500
      GO TO 140                                                          OPT25510
130   IF (L .NE. M) H(K,K-1)=-H(K,K-1)                                   OPT25520
140   P=P+S                                                              OPT25530
      X=P/S                                                              OPT25540
      Y=Q/S                                                              OPT25550
      ZZ=R/S                                                             OPT25560
      Q=Q/P                                                              OPT25570
      R=R/P                                                              OPT25580
C-----------------------------ROW MODIFICATION-------------------------OPT25590
      DO 160 J=K,N                                                       OPT25600
      P=H(K,J)+Q*H(K+1,J)                                                OPT25610
      IF (.NOT. NOTLAS) GO TO 150                                        OPT25620
      P=P+R*H(K+2,J)                                                     OPT25630
      H(K+2,J)=H(K+2,J)-P*ZZ                                             OPT25640
150   H(K+1,J)=H(K+1,J)-P*Y                                              OPT25650
      H(K,J)=H(K,J)-P*X                                                  OPT25660
160   CONTINUE                                                           OPT25670
      J=MINO(EN,K+3)                                                     OPT25680
C-------------------------COLUMN MODIFICATION-------------------------OPT25690
      DO 180 I=1,J                                                       OPT25700
      P=X*H(I,K)+Y*H(I,K+1)                                              OPT25710
      IF (.NOT. NOTLAS) GO TO 170                                        OPT25720
      P=P+ZZ*H(I,K+2)                                                    OPT25730
      H(I,K+2)=H(I,K+2)-P*R                                              OPT25740
170   H(I,K+1)=H(I,K+1)-P*Q                                              OPT25750
      H(I,K)=H(I,K)-P                                                    OPT25760
180   CONTINUE                                                           OPT25770
C-----------------------ACCUMULATE TRANSFORMATIONS--------------------OPT25780
      DO 200 I=LOW,IGH                                                   OPT25790
      P=X*Z(I,K)+Y*Z(I,K+1)                                              OPT25800
      IF (.NOT. NOTLAS) GO TO 190                                        OPT25810
      P=P+ZZ*Z(I,K+2)                                                    OPT25820
      Z(I,K+2)=Z(I,K+2)-P*R                                              OPT25830
190   Z(I,K+1)=Z(I,K+1)-P*Q                                              OPT25840
      Z(I,K)=Z(I,K)-P                                                    OPT25850
200   CONTINUE                                                           OPT25860
210   CONTINUE                                                           OPT25870
      GO TO 40                                                           OPT25880
C-----------------------------ONE ROOT FOUND---------------------------OPT25890
220   H(EN,EN)=X+T                                                       OPT25900
      WR(EN)=H(EN,EN)                                                    OPT25910
      WI(EN)=0.0D0                                                       OPT25920
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```
      EN=NA                                                              OPT25930
      GO TO 30                                                           OPT25940
C-----------------------------TWO ROOTS FOUND-----------------------------OPT25950
220   P=(Y - X)/2.0D0                                                    OPT25960
      Q=P*P+W                                                            OPT25970
      ZZ=DSQRT(DABS(Q))                                                  OPT25980
      H(EN,EN)=X+T                                                       OPT25990
      X=H(EN,EN)                                                         OPT26000
      H(NA,NA)=Y+T                                                       OPT26010
      IF (Q .LT. 0.0D0) GO TO 270                                        OPT26020
C-------------------------------REAL PAIR-----------------------------------OPT26030
      ZZ=P+DSIGN(ZZ,P)                                                   OPT26040
      WR(NA)=X+ZZ                                                        OPT26050
      WR(EN)=WR(NA)                                                      OPT26060
      IF (ZZ .NE. 0.0D0) WR(EN)=X-W/ZZ                                   OPT26070
      WI(NA)=0.0D0                                                       OPT26080
      WI(EN)=0.0D0                                                       OPT26090
      X=H(EN,NA)                                                         OPT26100
      S=DABS(X)+DABS(ZZ)                                                 OPT26110
      P=X/S                                                              OPT26120
      Q=ZZ/S                                                             OPT26130
      R=DSQRT(P*P+Q*Q)                                                   OPT26140
      P=P/R                                                              OPT26150
      Q=Q/R                                                              OPT26160
C-----------------------------ROW MODIFICATION----------------------------OPT26170
      DO 240 J=NA,N                                                      OPT26180
      ZZ=H(NA,J)                                                         OPT26190
      H(NA,J)=Q*ZZ+P*H(EN,J)                                             OPT26200
      H(EN,J)=Q*H(EN,J)-P*ZZ                                             OPT26210
240   CONTINUE                                                           OPT26220
C--------------------------COLUMN MODIFICATION----------------------------OPT26230
      DO 250 I=1,EN                                                      OPT26240
      ZZ=H(I,NA)                                                         OPT26250
      H(I,NA)=Q*ZZ+P*H(I,EN)                                             OPT26260
      H(I,EN)=Q*H(I,EN)-P*ZZ                                             OPT26270
250   CONTINUE                                                           OPT26280
C----------------------ACCUMULATE TRANSFORMATIONS--------------------------OPT26290
      DO 260 I=LOW,IGH                                                   OPT26300
      ZZ=Z(I,NA)                                                         OPT26310
      Z(I,NA)=Q*ZZ+P*Z(I,EN)                                             OPT26320
      Z(I,EN)=Q*Z(I,EN)-P*ZZ                                             OPT26330
260   CONTINUE                                                           OPT26340
      GO TO 280                                                          OPT26350
C-------------------------------COMPLEX PAIR--------------------------------OPT26360
270   WR(NA)=X+P                                                         OPT26370
      WR(EN)=X+P                                                         OPT26380
      WI(NA)=ZZ                                                          OPT26390
      WI(EN)=-ZZ                                                         OPT26400
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      EN=ENM2                                                          OPT26410
      GO TO 30                                                         OPT26420
C-----------------ALL ROOTS FOUND.  BACKSUBSTITUTE TO FIND-----------OPT26430
C-----------------VECTORS OF UPPER TRIANGULAR FORM----------------------OPT26440
290   IF (NORM .EQ. 0.0D0) GO TO 510                                   OPT26450
      DO 450 NN=1,N                                                    OPT26460
      EN=N+1-NN                                                        OPT26470
      P=WR(EN)                                                         OPT26480
      Q=WI(EN)                                                         OPT26490
      NA=EN-1                                                          OPT26500
      IF (Q) 370,300,450                                               OPT26510
C-----------------------------REAL VECTOR-------------------------------OPT26520
300   M=EN                                                             OPT26530
      H(EN,EN)=1.0D0                                                   OPT26540
      IF (NA .EQ. 0) GO TO 450                                         OPT26550
      DO 360 II=1,NA                                                   OPT26560
      I=EN-II                                                          OPT26570
      W=H(I,I)-P                                                       OPT26580
      R=H(I,EN)                                                        OPT26590
      IF (M .GT. NA) GO TO 320                                         OPT26600
      DO 310 J=M,NA                                                    OPT26610
310   R=R+H(I,J)*H(J,EN)                                               OPT26620
320   IF (WI(I) .GE. 0.0D0) GO TO 330                                  OPT26630
      ZZ=W                                                             OPT26640
      S=R                                                              OPT26650
      GO TO 360                                                        OPT26660
330   M=I                                                              OPT26670
      IF (WI(I) .NE. 0.0D0) GO TO 340                                  OPT26680
      T=W                                                              OPT26690
      IF (W .EQ. 0.0D0) T=MACHEP*NORM                                  OPT26700
      H(I,EN)=-R/T                                                     OPT26710
      GO TO 360                                                        OPT26720
C-------------------------SOLVE REAL EQUATIONS-------------------------OPT26730
340   X=H(I,I+1)                                                       OPT26740
      Y=H(I+1,I)                                                       OPT26750
      Q=(WR(I) - P)*(WR(I) - P)+WI(I)*WI(I)                            OPT26760
      T=(X * S - ZZ * R)/Q                                             OPT26770
      H(I,EN)=T                                                        OPT26780
      IF (DABS(X) .LE. DABS(ZZ)) GO TO 350                             OPT26790
      H(I+1,EN)=(-R - W * T)/X                                         OPT26800
      GO TO 360                                                        OPT26810
350   H(I+1,EN)=(-S - Y * T)/ZZ                                        OPT26820
360   CONTINUE                                                         OPT26830
C-----------------------------END REAL VECTOR---------------------------OPT26840
      GO TO 450                                                        OPT26850
C-----------------------------COMPLEX VECTOR----------------------------OPT26860
370   M=NA                                                             OPT26870
C-----------------LAST VECTOR COMPONENT CHOSEN IMAGINARY SO THAT---------OPT26880
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C----------------EIGENVECTOR MATRIX IS TRIANGULAR----------------------OPT26890
      IF (DABS(H(EN,NA)) .LE. DABS(H(NA,EN))) GO TO 380                 OPT26900
      H(NA,NA)=Q/H(EN,NA)                                               OPT26910
      H(NA,EN)=-(H(EN,EN) - P)/H(EN,NA)                                 OPT26920
      GO TO 390                                                         OPT26930
380   Z3=DCMPLX(C.0D0,-H(NA,EN))/DCMPLX(H(NA,NA)-P,Q)                   OPT26940
      H(NA,NA)=DREAL(Z3)                                                OPT26950
      H(NA,EN)=DIMAG(Z3)                                                OPT26960
390   H(EN,NA)=0.0D0                                                    OPT26970
      H(EN,EN)=1.0D0                                                    OPT26980
      ENM2=NA-1                                                         OPT26990
      IF (ENM2 .EQ. 0) GO TO 450                                        OPT27000
      DO 440 II=1,ENM2                                                  OPT27010
      I=NA-II                                                           OPT27020
      W=H(I,I)-P                                                        OPT27030
      RA=0.0D0                                                          OPT27040
      SA=H(I,EN)                                                        OPT27050
      DO 400 J=M,NA                                                     OPT27060
      RA=RA+H(I,J)*H(J,NA)                                              OPT27070
      SA=SA+H(I,J)*H(J,EN)                                              OPT27080
400   CONTINUE                                                          OPT27090
      IF (WI(I) .GE. 0.0D0) GO TO 410                                   OPT27100
      ZZ=W                                                              OPT27110
      R=RA                                                              OPT27120
      S=SA                                                              OPT27130
      GO TO 440                                                         OPT27140
410   M=I                                                               OPT27150
      IF (WI(I) .NE. 0.0D0) GO TO 420                                   OPT27160
      Z3=DCMPLX(-RA,-SA)/DCMPLX(W,Q)                                    OPT27170
      H(I,NA)=DREAL(Z3)                                                 OPT27180
      H(I,EN)=DIMAG(Z3)                                                 OPT27190
      GO TO 440                                                         OPT27200
C------------------------SOLVE COMPLEX EQUATIONS----------------------OPT27210
420   X=H(I,I+1)                                                        OPT27220
      Y=H(I+1,I)                                                        OPT27230
      VR=(WR(I) - P)*(WR(I) - P)+WI(I)*WI(I)-Q*Q                        OPT27240
      VI=(WR(I) - P)*2.0D0*Q                                            OPT27250
      IF (VR .EQ. 0.0D0 .AND. VI .EQ. 0.0D0) VR=MACHEP*NORM*(DABS(W) + DOPT27260
     1ABS(Q) + DABS(X) + DABS(Y) + DABS(ZZ))                            OPT27270
      Z3=DCMPLX(X*R-ZZ*RA+Q*SA,X*S-ZZ*SA-Q*RA)/DCMPLX(VR,VI)            OPT27280
      H(I,NA)=DREAL(Z3)                                                 OPT27290
      H(I,EN)=DIMAG(Z3)                                                 OPT27300
      IF (DABS(X) .LE. DABS(ZZ) + DABS(Q)) GO TO 430                    OPT27310
      H(I+1,NA)=(-RA - W * H(I,NA) + Q * H(I,EN))/X                     OPT27320
      H(I+1,EN)=(-SA - W * H(I,EN) - Q * H(I,NA))/X                     OPT27330
      GO TO 440                                                         OPT27340
430   Z3=DCMPLX(-R-Y*H(I,NA),-S-Y*H(I,EN))/DCMPLX(ZZ,Q)                 OPT27350
      H(I+1,NA)=DREAL(Z3)                                               OPT27360
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      H(I+1,EN)=DIMAG(Z3)                                                OPT27370
440   CONTINUE                                                           OPT27380
C-----------------------------END COMPLEX VECTOR-----------------------OPT27390
450   CONTINUE                                                           OPT27400
C---------------END BACK SUBSTITUTION. VECTORS OF ISOLATED ROOTS---------OPT27410
      DO 470 I=1,N                                                       OPT27420
      IF (I .GE. LOW .AND. I .LE. IGH) GO TO 470                         OPT27430
      DO 460 J=I,N                                                       OPT27440
460   Z(I,J)=H(I,J)                                                      OPT27450
470   CONTINUE                                                           OPT27460
C----------------MULTIPLY BY TRANSFORMATION MATRIX TO GIVE--------------OPT27470
C----------------VECTORS OF ORIGINAL FULL MATRIX.----------------------OPT27480
      DO 490 JJ=LOW,N                                                    OPT27490
      J=N+LOW-JJ                                                         OPT27500
      M=MIN0(J,IGH)                                                      OPT27510
      DO 490 I=LOW,IGH                                                   OPT27520
      ZZ=0.0D0                                                           OPT27530
      DO 480 K=LOW,M                                                     OPT27540
480   ZZ=ZZ+Z(I,K)*H(K,J)                                                OPT27550
      Z(I,J)=ZZ                                                          OPT27560
490   CONTINUE                                                           OPT27570
      GO TO 510                                                          OPT27580
C----------------SET ERROR -->NO CONVERGENCE TO AN----------------------OPT27590
C----------------EIGENVALUE AFTER 30 ITERATIONS------------------------OPT27600
500   IERR=EN                                                            OPT27610
510   RETURN                                                             OPT27620
      END                                                                OPT27630
C=================================================================OPT27640
      SUBROUTINE BALBAK (NM,N,LOW,IGH,SCALE,M,Z)                         OPT27650
      INTEGER I,J,K,M,N,II,NM,IGH,LOW                                    OPT27660
      REAL*8 SCALE(N),Z(NM,M),S                                          OPT27670
      IF (M .EQ. 0) GO TO 60                                             OPT27680
      IF (IGH .EQ. LOW) GO TO 30                                         OPT27690
      DO 20 I=LOW,IGH                                                    OPT27700
      S=SCALE(I)                                                         OPT27710
C----------------LEFT HAND EIGENVECTORS ARE BACK TRANSFORMED------------OPT27720
C----------------IF THE FOREGOING STATEMENT IS REPLACED BY--------------OPT27730
C----------------S=1.0D0/SCALE(I).--------------------------------------OPT27740
      DO 10 J=1,M                                                        OPT27750
10    Z(I,J)=Z(I,J)*S                                                    OPT27760
20    CONTINUE                                                           OPT27770
30    DO 50 II=1,N                                                       OPT27780
      I=II                                                               OPT27790
      IF (I .GE. LOW .AND. I .LE. IGH) GO TO 50                          OPT27800
      IF (I .LT. LOW) I=LOW-II                                           OPT27810
      K=SCALE(I)                                                         OPT27820
      IF (K .EQ. I) GO TO 50                                             OPT27830
      DO 40 J=1,M                                                        OPT27840
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      S=Z(I,J)                                                          OPT27850
      Z(I,J)=Z(K,J)                                                     OPT27860
      Z(K,J)=S                                                          OPT27870
40    CONTINUE                                                          OPT27880
50    CONTINUE                                                          OPT27890
60    RETURN                                                            OPT27900
      END                                                               OPT27910
C=====================================================================OPT27920
      SUBROUTINE HQR (NM,N,LOW,IGH,H,WR,WI,IERR)                        OPT27930
      INTEGER I,J,K,L,M,N,EN,LL,MM,NA,NM,IGH,ITS,LOW,MP2,ENM2,IERR      OPT27940
      REAL*8 H(NM,N),WR(N),WI(N)                                        OPT27950
      REAL*8 P,Q,R,S,T,W,X,Y,ZZ,NORM,MACHEP                             OPT27960
      REAL*8 DSQRT,DABS,DSIGN                                           OPT27970
      INTEGER MIN0                                                      OPT27980
      LOGICAL NOTLAS                                                    OPT27990
      DATA MACHEP/Z3410000000000000/                                    OPT28000
      IERR=0                                                            OPT28010
      NORM=0.0D0                                                        OPT28020
      K=1                                                               OPT28030
C--------STORE ROOTS ISOLATED BY BALANC AND COMPUTE MATRIX NORM---------OPT28040
      DO 20 I=1,N                                                       OPT28050
      DO 10 J=K,N                                                       OPT28060
10    NORM=NORM+DABS(H(I,J))                                            OPT28070
      K=I                                                               OPT28080
      IF (I .GE. LOW .AND. I .LE. IGH) GO TO 20                         OPT28090
      WR(I)=H(I,I)                                                      OPT28100
      WI(I)=0.0D0                                                       OPT28110
20    CONTINUE                                                          OPT28120
      EN=IGH                                                            OPT28130
      T=0.0D0                                                           OPT28140
C----------------------SEARCH FOR NEXT EIGENVALUES--------------------OPT28150
30    IF (EN .LT. LOW) GO TO 250                                        OPT28160
      ITS=0                                                             OPT28170
      NA=EN-1                                                           OPT28180
      ENM2=NA-1                                                         OPT28190
C----------------LOOK FOR SINGLE SMALL SUB-DIAGONAL ELEMENT-------------OPT28200
40    DO 50 LL=LOW,EN                                                   OPT28210
      L=EN+LOW-LL                                                       OPT28220
      IF (L .EQ. LOW) GO TO 60                                          OPT28230
      S=DABS(H(L-1,L-1))+DABS(H(L,L))                                   OPT28240
      IF (S .EQ. 0.0D0) S=NORM                                          OPT28250
      IF (DABS(H(L,L-1)) .LE. MACHEP * S) GO TO 60                      OPT28260
50    CONTINUE                                                          OPT28270
C----------------------------FORM SHIFT--------------------------------OPT28280
60    X=H(EN,EN)                                                        OPT28290
      IF (L .EQ. EN) GO TO 200                                          OPT28300
      Y=H(NA,NA)                                                        OPT28310
      W=H(EN,NA)*H(NA,EN)                                               OPT28320
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      IF (L .EQ. NA) GO TO 210                                          OPT28330
      IF (ITS .EQ. 30) GO TO 240                                        OPT28340
      IF (ITS .NE. 10 .AND. ITS .NE. 20) GO TO 80                       OPT28350
C-----------------------FORM EXCEPTIONAL SHIFT-------------------------OPT28360
      T=T+X                                                             OPT28370
      DO 70 I=LOW,EN                                                    OPT28380
70    H(I,I)=H(I,I)-X                                                   OPT28390
      S=DABS(H(EN,NA))+DABS(H(NA,ENM2))                                 OPT28400
      X=0.75D0*S                                                        OPT28410
      Y=X                                                               OPT28420
      W=-0.4375D0*S*S                                                   OPT28430
80    ITS=ITS+1                                                         OPT28440
C----------LOOK FOR TWO CONSECUTIVE SMALL SUB-DIAGONAL ELEMENTS.--------OPT28450
      DO 90 MM=L,ENM2                                                   OPT28460
      M=ENM2+L-MM                                                       OPT28470
      ZZ=H(M,M)                                                         OPT28480
      R=X-ZZ                                                            OPT28490
      S=Y-ZZ                                                            OPT28500
      P=(R * S - W)/H(M+1,M)+H(M,M+1)                                   OPT28510
      Q=H(M+1,M+1)-ZZ-R-S                                               OPT28520
      R=H(M+2,M+1)                                                      OPT28530
      S=DABS(P)+DABS(Q)+DABS(R)                                         OPT28540
      P=P/S                                                             OPT28550
      Q=Q/S                                                             OPT28560
      R=R/S                                                             OPT28570
      IF (M .EQ. L) GO TO 100                                           OPT28580
      IF (DABS(H(M,M-1)) * (DABS(Q) + DABS(R)) .LE. MACHEP * DABS(P)    OPT28590
     1 * (DABS(H(M-1,M-1)) + DABS(ZZ) + DABS(H(M+1,M+1)))) GO TO 100    OPT28600
90    CONTINUE                                                          OPT28610
100   MP2=M+2                                                           OPT28620
      DO 110 I=MP2,EN                                                   OPT28630
      H(I,I-2)=0.0D0                                                    OPT28640
      IF (I .EQ. MP2) GO TO 110                                         OPT28650
      H(I,I-3)=0.0D0                                                    OPT28660
110   CONTINUE                                                          OPT28670
C------DOUBLE QR STEP INVOLVING ROWS L TO EN AND COLUMNS M TO EN--------OPT28680
      DO 190 K=M,NA                                                     OPT28690
      NOTLAS=K.NE.NA                                                    OPT28700
      IF (K .EQ. M) GO TO 120                                           OPT28710
      P=H(K,K-1)                                                        OPT28720
      Q=H(K+1,K-1)                                                      OPT28730
      R=0.0D0                                                           OPT28740
      IF (NOTLAS) R=H(K+2,K-1)                                          OPT28750
      X=DABS(P)+DABS(Q)+DABS(R)                                         OPT28760
      IF (X .EQ. 0.0D0) GO TO 190                                       OPT28770
      P=P/X                                                             OPT28780
      Q=Q/X                                                             OPT28790
      R=R/X                                                             OPT28800
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```
120   S=DSIGN(DSQRT(P*P+Q*Q+R*R),P)                                    OPT28810
      IF (K .EQ. M) GO TO 130                                          OPT28820
      H(K,K-1)=-S*X                                                    OPT28830
      GO TO 140                                                        OPT28840
130   IF (L .NE. M) H(K,K-1)=-H(K,K-1)                                 OPT28850
140   P=P+S                                                            OPT28860
      X=P/S                                                            OPT28870
      Y=Q/S                                                            OPT28880
      ZZ=R/S                                                           OPT28890
      Q=Q/P                                                            OPT28900
      R=R/P                                                            OPT28910
C-----------------------------ROW MODIFICATION-------------------------OPT28920
      DO 160 J=K,EN                                                    OPT28930
      P=H(K,J)+Q*H(K+1,J)                                              OPT28940
      IF (.NOT. NOTLAS) GO TO 150                                      OPT28950
      P=P+R*H(K+2,J)                                                   OPT28960
      H(K+2,J)=H(K+2,J)-P*ZZ                                           OPT28970
150   H(K+1,J)=H(K+1,J)-P*Y                                            OPT28980
      H(K,J)=H(K,J)-P*X                                                OPT28990
160   CONTINUE                                                         OPT29000
      J=MINO(EN,K+3)                                                   OPT29010
C-----------------------------COLUMN MODIFICATION----------------------OPT29020
      DO 180 I=L,J                                                     OPT29030
      P=X*H(I,K)+Y*H(I,K+1)                                            OPT29040
      IF (.NOT. NOTLAS) GO TO 170                                      OPT29050
      P=P+ZZ*H(I,K+2)                                                  OPT29060
      H(I,K+2)=H(I,K+2)-P*R                                            OPT29070
170   H(I,K+1)=H(I,K+1)-P*Q                                            OPT29080
      H(I,K)=H(I,K)-P                                                  OPT29090
180   CONTINUE                                                         OPT29100
190   CONTINUE                                                         OPT29110
      GO TO 40                                                         OPT29120
C-----------------------------ONE ROOT FOUND---------------------------OPT29130
200   WR(EN)=X+T                                                       OPT29140
      WI(EN)=0.0D0                                                     OPT29150
      EN=NA                                                            OPT29160
      GO TO 30                                                         OPT29170
C-----------------------------TWO ROOTS FOUND--------------------------OPT29180
210   P=(Y - X)/2.0D0                                                  OPT29190
      Q=P*P+W                                                          OPT29200
      ZZ=DSQRT(DABS(Q))                                                OPT29210
      X=X+T                                                            OPT29220
      IF (Q .LT. 0.0D0) GO TO 220                                      OPT29230
C-----------------------------REAL PAIR--------------------------------OPT29240
      ZZ=P+DSIGN(ZZ,P)                                                 OPT29250
      WR(NA)=X+ZZ                                                      OPT29260
      WR(EN)=WR(NA)                                                    OPT29270
      IF (ZZ .NE. 0.0D0) WR(EN)=X-W/ZZ                                 OPT29280
```

```
      WI(NA)=0.0D0                                                          OPT29290
      WI(EN)=0.0DC                                                          OPT29300
      GO TO 230                                                             OPT29310
C-----------------------------COMPLEX PAIR-------------------------------OPT29320
220   WR(NA)=X+P                                                            OPT29330
      WR(EN)=X+P                                                            OPT29340
      WI(NA)=ZZ                                                             OPT29350
      WI(EN)=-ZZ                                                            OPT29360
230   EN=ENM2                                                               OPT29370
      GO TO 30                                                              OPT29380
C----------------SET ERROR -- NO CONVERGENCE TO AN----------------------OPT29390
C----------------EIGENVALUE AFTER 30 ITERATIONS------------------------OPT29400
240   IERR=EN                                                               OPT29410
250   RETURN                                                                OPT29420
      END                                                                   OPT29430
C=====================================================================OPT29440
      SUBROUTINE PSDCAL (N2,NS,FA,X,NC,GW,GV ,C ,NG,HY,HU,H,                OPT29450
     1  FBGE,NG,GAM,ACL,F,WR,WI,D1,D2,JCF,RES,Q,R,BE,CC,IYU,                OPT29460
     2  IPSD,INORM)                                                         OPT29470
C=====================================================================OPT29480
C     =  PSDCAL COMPUTES THE PSD OF OUTPUTS OR CONTROLS OF              =OPT29490
C     =   A CONTROLLED SYSTEM                                           =OPT29500
C     =                                                                 =OPT29510
C     =      IYU= 1     OUTPUT PSD                                      =OPT29520
C     =         = 2     CONTROL PSD                                     =OPT29530
C     =         = 3     BOTH OUTPUT AND CONTROL PSD                     =OPT29540
C     =                                                                 =OPT29550
C     =      IPSD=1     PSD                                             =OPT29560
C     =          =2     PSD AND TF RESIDUES                             =OPT29570
C     =                                                                 =OPT29580
C     =                                                                 =OPT29590
C     =      INORM=     1,2,... NG  NORMALIZED BY ITH PROCESS NOISE     =OPT29600
C     =                 NG+1,... NG+NO NORMALIZED BY ITH MEAS NOISE   =  OPT29610
C=====================================================================OPT29620
      DOUBLE PRECISION FA,X,GW,GV,C,HY,H,FBGE,GAM,ACL,F,WR,WI,D1,D2,RES,OPT29630
     1BB,CC,G,R,PSD,W,DNORM,DN1,EMAX,ELOG,EMOD,DW,ST,CM,RE,AI,HU,DW1     OPT29640
      COMPLEX *16ZD,ZN,ZZ                                                  OPT29650
      DIMENSION FA(N2,N2),X(N2,N2),GW(N2,NG),C(NC,NS),HY(NC,N2),H(NC,NS)OPT29660
     1,FBGE(NS,NC),GAM(NS,NG),ACL(NS,NS),F(NS,NS),WR(N2),WI(N2),D1(N2),DOPT29670
     22(N2),RES(N2),Q(NG,NG),R(NC,NC),PSD(30),W(30),BE(N2),CC(N2),GV(N2,OPT29680
     3NO),HU(NC,N2),DW1(4)                                                OPT29690
      INTEGER JCF(N2)                                                      OPT29700
      DATA DW1/1.D0,2.D0,5.D0,10.D0/                                       OPT29710
      IF (IYU .EQ. 0) IYU=1                                                OPT29720
      IF (INORM .EQ. 0) INORM=1                                            OPT29730
      IPT=0                                                                OPT29740
      IF (IPSD .GT. 1) IPT=1                                               OPT29750
      IX=INORM-NG                                                          OPT29760
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      IF (IX .GT. 0) WRITE (6,330) IX                                   OPT29770
      IF (IX .LE. 0) WRITE (6,340) INORM                                OPT29780
      NSQ=N2*N2                                                         OPT29790
C---------COMPUTE EIGENSYSTEM OF CONTROLLED SYSTEM; FORM FA-------------OPT29800
      DO 10 I=1,NS                                                      OPT29810
      DO 10 J=1,NS                                                      OPT29820
      FA(I,J)=ACL(I,J)                                                  OPT29830
10    FA(NS+I,J)=0.DO                                                   OPT29840
      DO 30 I=1,NS                                                      OPT29850
      DO 30 J=1,NS                                                      OPT29860
      ST=0.DO                                                           OPT29870
      DO 20 K=1,NC                                                      OPT29880
20    ST=ST+FBGE(I,K)*H(K,J)                                            OPT29890
      FA(I,NS+J)=-ST                                                    OPT29900
30    FA(NS+I,NS+J)=F(I,J)-ST                                           OPT29910
      CALL RAPRNT (N2,N2,N2,9,FA,4,'(9(1X,1PD13.6))')                   OPT29920
C-------------------------------DEBUG ABOVE-------------------------------OPT29930
      CALL BALANC (N2,N2,FA,LOW,IHIGH,D1)                               OPT29940
      CALL ORTHES (N2,N2,LOW,IHIGH,FA,D2)                               OPT29950
      CALL ORTRAN (N2,N2,LOW,IHIGH,FA,D2,X)                             OPT29960
      CALL HQR2 (N2,N2,LOW,IHIGH,FA,WR,WI,X,IERR)                       OPT29970
      IF (IERR .NE. 0) GO TO 320                                        OPT29980
      CALL BALBAK (N2,N2,LOW,IHIGH,D1,N2,X)                             OPT29990
      CALL RAPRNT (N2,N2,N2,9,X,4,'(9(1X,1PD13.6))')                    OPT30000
C-----------DEBUG ABOVE;DETERMINE MODAL MATRICES----------------------OPT30010
      IF (IYU .EQ. 1) GO TO 60                                          OPT30020
C-----------------------------HSUBU-------------------------------------OPT30030
      DO 50 I=1,NC                                                      OPT30040
      DO 50 J=1,N2                                                      OPT30050
      ST=0.DO                                                           OPT30060
      DO 40 K=1,NS                                                      OPT30070
40    ST=ST-C(I,K)*X(K,J)                                               OPT30080
50    HU(I,J)=ST                                                        OPT30090
      GO TO 90                                                          OPT30100
C-----------------------------HSUBY-------------------------------------OPT30110
60    DO 80 I=1,NC                                                      OPT30120
      DO 80 J=1,N2                                                      OPT30130
      ST=0.DO                                                           OPT30140
      DO 70 K=1,NS                                                      OPT30150
70    ST=ST+H(I,K)*X(K,J)-H(I,K)*X(NS+K,J)                              OPT30160
80    HY(I,J)=ST                                                        OPT30170
      CALL RAPRNT (NO,NC,N2,9,HY,4,'(9(1X,1PD13.6))')                   OPT30180
C-------------------------DEBUG ABOVE-----------------------------------OPT30190
90    CALL MINV (NSQ,X,N2,ST,D1,D2)                                     OPT30200
      CALL RAPRNT (N2,N2,N2,9,X,4,'(9(1X,1PD13.6))')                    OPT30210
C-------------------------DEBUG ABOVE-----------------------------------OPT30220
C-------------------------GSUBW-----------------------------------------OPT30230
      DO 110 I=1,N2                                                     OPT30240
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      DO 110 J=1,NG                                                     OPT30250
      ST=0.0D0                                                          OPT30260
      DO 100 K=1,NS                                                     OPT30270
100   ST=ST-X(I,NS+K)*GAM(K,J)                                          OPT30280
110   GW(I,J)=ST                                                        OPT30290
      CALL RAPRNT (N2,N2,NG,9,GW,4,'(9(1X,1PD13.6))')                   OPT30300
C----------DEBUG ABOVE; USE SELECTED NORMALIZATION----------------------OPT30310
      IF (INORM .LE. NG) DNORM=1.D0/Q(INORM,INORM)                      OPT30320
      IF (INORM .GT. NG) DNORM=1.D0/R(INORM-NG,INORM-NG)                OPT30330
C----------------DETERMINE BANDWIDTH OF CONTROLLED SYSTEM---------------OPT30340
      EMAX=0.D0                                                         OPT30350
      DO 120 I=1,N2                                                     OPT30360
      EMOD=DABS(WR(I)**2 +WI(I)**2)                                     OPT30370
      IF (EMOD .GT. EMAX) EMAX=EMOD                                     OPT30380
120   CONTINUE                                                          OPT30390
      EMOD=DSQRT(EMAX)                                                  OPT30400
      EMOD=2*EMOD                                                       OPT30410
C----------------------ROUND UP TO NEAREST 2,4,5,8,10-------------------OPT30420
      ELOG=DLOG10(EMOD)                                                 OPT30430
      IF (ELOG .LT. 0.D0) IPOW=-IDINT(DABS(ELOG) + 1)                   OPT30440
      IF (ELOG .GE. 0.D0) IPOW=IDINT(ELOG)                              OPT30450
      EMAX=EMOD*10**(-IPOW)                                             OPT30460
      IF (EMAX .GT. 2.D0) EMOD=2.D0                                     OPT30470
      IF (EMAX .GT. 4.D0) EMOD=4.D0                                     OPT30480
      IF (EMAX .GT. 5.D0) EMOD=5.D0                                     OPT30490
      IF (EMAX .GT. 8.D0) EMOD=8.D0                                     OPT30500
      IF (EMAX .GE. 10.D0) EMOD=10.D0                                   OPT30510
      EMAX=EMOD*10**IPOW                                                OPT30520
      DW=EMAX/20.D0                                                     OPT30530
C----------------------ADD 10 POINTS 3 DECADES UP-----------------------OPT30540
      IF (EMOD .LT. 5.0) GO TO 130                                      OPT30550
      EMAX=1.0D1                                                        OPT30560
      IK=3                                                              OPT30570
      GO TO 140                                                         OPT30580
130   EMAX=5.D0                                                         OPT30590
      IK=2                                                              OPT30600
140   CONTINUE                                                          OPT30610
C----------------------STORE 30 FREQUENCIES-----------------------------OPT30620
      DO 150 I=1,20                                                     OPT30630
150   W(I)=DW*(I-1)                                                     OPT30640
      DO 160 I=1,3                                                      OPT30650
      IP=20+3*(I-1)                                                     OPT30660
      DO 160 J=1,3                                                      OPT30670
      IX=MOD(IK+J-1,3)+1                                                OPT30680
      JJ=0                                                              OPT30690
      IF (IK .EQ. 2 .AND. J .GE. 2) JJ=1                                OPT30700
      W(IP+J)=DW1(IX)*10**(IPOW+I-1+JJ+IK-2)                            OPT30710
160   CONTINUE                                                          OPT30720
```

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      IX=MOD(IK,2)+1                                                    OPT30730
      W(30)=DW1(IX)*10**(IPOW+3 +IK-2)                                  OPT30740
C-----------------------LARGE LOOP THRU OUTPUTS-------------------------OPT30750
      IF (IYU .EQ. 1) NL=NC                                             OPT30760
      IF (IYU .EQ. 2) NL=NC                                             OPT30770
      DO 310 L=1,NL                                                     OPT30780
      DO 170 I=1,20                                                     OPT30790
170   PSD(I)=0.DO                                                       OPT30800
C-----------------------LOOP THRU PROCESS NOISE-------------------------OPT30810
      DO 220 I=1,NG                                                     OPT30820
      DN1=DNORM*G(I,I)                                                  OPT30830
      IF (IYU .EQ. 1 .AND. IPT .EQ. 1) WRITE (6,350) I,L                OPT30840
      IF (IYU .EQ. 2 .AND. IPT .EQ. 1) WRITE (6,360) I,L                OPT30850
      IF (IYU.EQ.1) CALL RESID (I,L,N2,JCF,NG,GW,NL,HY,WR,WI,           OPT30860
     1RES,BB,CC,IFT)                                                    OPT30870
      IF (IYU.EQ.2) CALL RESID (I,L,N2,JCF,NG,GW,NL,HU,WR,WI,           OPT30880
     1RES,BB,CC,IFT)                                                    OPT30890
      DO 210 K=1,20                                                     OPT30900
      ZZ=DCMPLX(0.DO,0.DO)                                              OPT30910
      OM=W(K)                                                           OPT30920
      DO 200 II=1,N2                                                    OPT30930
      IF (WI(II)) 200,180,190                                           OPT30940
180   ZD=DCMPLX(-WR(II),OM-WI(II))                                      OPT30950
      ZZ=RES(II)/ZD+ZZ                                                  OPT30960
      GO TO 200                                                         OPT30970
190   RE=WR(II)                                                         OPT30980
      AI=WI(II)                                                         OPT30990
      ZD=DCMPLX(RE**2 + AI**2 - OM**2,-2.DO*RE*OM)                      OPT31000
      ZN=DCMPLX(RES(II+1)*AI-RES(II)*RE,RES(II)*OM)                     OPT31010
      ZZ=ZZ+ZN/ZD                                                       OPT31020
200   CONTINUE                                                          OPT31030
210   PSD(K)=PSD(K)+DN1*(ZZ*DCONJG(ZZ))                                 OPT31040
220   CONTINUE                                                          OPT31050
C-----------------------------GSUBV-------------------------------------OPT31060
      DO 240 I=1,N2                                                     OPT31070
      DO 240 J=1,NC                                                     OPT31080
      ST=0.DO                                                           OPT31090
      DO 230 K=1,NS                                                     OPT31100
230   ST=ST+X(I,K)*FBGE(K,J)+X(I,NS+K)*FBGE(K,J)                        OPT31110
240   GV(I,J)=ST                                                        OPT31120
      CALL RAPRNT (N2,N2,NC,9,GV,4,'(9(1X,1PD13.6))')                   OPT31130
C-----------------DEBUG ABOVE, LOOP THRU MEAS NOISE---------------------OPT31140
      DO 300 I=1,NC                                                     OPT31150
      DN1=DNORM*R(I,I)                                                  OPT31160
      IF (IYU .EQ. 1 .AND. IPT .EQ. 1) WRITE (6,370) I,L                OPT31170
      IF (IYU .EQ. 2 .AND. IPT .EQ. 1) WRITE (6,380) I,L                OPT31180
      IF (IYU.EQ.1) CALL RESID (I,L,N2,JCF,NO,GV,NL,HY,WR,WI,RES,       OPT31190
     1    BB,CC,IFT)                                                    OPT31200
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      IF (IYU.EQ.2) CALL RESID (I,L,N2,JCF,NO,GV,NL,HU,WR,WI,RES,        OPT31210
     1    BB,CC,IFT)                                                     OPT31220
      DO 290 K=1,30                                                     OPT31230
      ZZ=DCMPLX(0.D0,0.D0)                                              OPT31240
      CM=W(K)                                                           OPT31250
      DO 270 II=1,N2                                                    OPT31260
      IF (WI(II)) 270,250,260                                           OPT31270
  250 ZD=DCMPLX(-WR(II),OM-WI(II))                                      OPT31280
      ZZ=ZZ+RES(II)/ZD                                                  OPT31290
      GO TO 270                                                         OPT31300
  260 RE=WR(II)                                                         OPT31310
      AI=WI(II)                                                         OPT31320
      ZD=DCMPLX(RE**2 + AI**2 -OM**2,-2.D0*RE*OM)                       OPT31330
      ZN=DCMPLX(RES(II+1)*AI-RES(II)*RE,RES(II)*CM)                     OPT31340
      ZZ=ZZ+ZN/ZD                                                       OPT31350
  270 CONTINUE                                                          OPT31360
      IF (IYU .EQ. 2 .OR. I .NE. L) GO TO 280                           OPT31370
      PSD(K)=PSD(K)+DN1                                                 OPT31380
  280 PSD(K)=PSD(K)+DN1*(ZZ*DCONJG(ZZ))                                 OPT31390
  290 CONTINUE                                                          OPT31400
  300 CONTINUE                                                          OPT31410
      IF (IYU .EQ. 1) WRITE (6,390) L                                   OPT31420
      IF (IYU .EQ. 2) WRITE (6,400) L                                   OPT31430
      WRITE (6,410) (W(I),PSD(I),I=1,30)                                OPT31440
  310 CONTINUE                                                          OPT31450
      RETURN                                                            OPT31460
  320 CONTINUE                                                          OPT31470
      CALL EPEXIT (N2,FA,IERR)                                          OPT31480
      RETURN                                                            OPT31490
C-----------------------------------------------------------------------OPT31500
  330 FORMAT (/,41H SUBSEQUENT PSD IS NORMALIZED BY MEAS NO.,I3,//)     OPT31510
  340 FORMAT (/,50H SUBSEQUENT PSD IS NORMALIZED BY PROCESS NOISE NO.,I3OPT31520
     ),//)                                                              OPT31530
  350 FORMAT (/38H TRANSFER FUNCTION FROM PROCESS NOISE ,I2,3H TO,13H MEOPT31540
     1ASUREMENT ,I2,//)                                                 OPT31550
  360 FORMAT (/36H TRANSFER FUNCTION FROM PROCESS NOISE ,I2,3H TO,9H CONOPT31560
     1TROL ,I2,//)                                                      OPT31570
  370 FORMAT (/36H TRANSFER FUNCTION FROM MEASUREMENT ,I2,16H TO MEASUREOPT31580
     1MENT ,I2,//)                                                      OPT31590
  380 FORMAT (/36H TRANSFER FUNCTION FROM MEASUREMENT ,I2,12H TO CONTPOLOPT31600
     1 ,I2,//)                                                          OPT31610
  390 FORMAT (/14H PSD OF OUTPUT,I3,32H  FORCED BY ALL NOISE-(RAD FREQ,,OPT31620
     115HNORMALIZED PSD)/)                                              OPT31630
  400 FORMAT (/15H PSD OF CONTROL,I3,32H  FORCED BY ALL NOISE-(RAD FREQ,OPT31640
     1,15HNORMALIZED PSD)/)                                             OPT31650
  410 FORMAT (4(1X,1H(,E11.4,1H,,E11.4,1H)))                            OPT31660
      END                                                               OPT31670
C=======================================================================OPT31680
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      SUBROUTINE EREXIT (N,A,IERR)                                      OPT31690
C     EREXIT RETURNS THE NUMBER OF THE EIGENVALUE WHERE HQR2          = OPT31700
C     FAILS, THEN STOPS THE PROGRAM.                                  = OPT31710
C=====================================================================  OPT31720
      INTEGER IERR                                                      OPT31730
      DOUBLE PRECISION A                                                OPT31740
      DIMENSION A(N,N)                                                  OPT31750
      WRITE (5,10) IERR                                                 OPT31760
      CALL RAPRNT (N,N,N,9,A,4,'(9(1X,1PD13.6))')                       OPT31770
      RETURN                                                            OPT31780
10    FORMAT (35H FAILURE IN HQR2 ON EIGENVALUE NO. ,I3)                OPT31790
      END                                                               OPT31800
C=====================================================================OPT31810
      SUBROUTINE READF (NS,ISAF,BA)                                     OPT31820
C     INTERACTIVELY INPUTS THE "F" MATRIX ELEMENT BY ELEMENT.         =OPT31830
C=====================================================================OPT31840
      REAL*8  BA(NS,NS),DUM,ANSR                                        OPT31850
      INTEGER I,J,K,L,IANS,ISAF                                         OPT31860
      DATA IY/'Y'/,IZ/'N'/                                              OPT31870
      IF (ISAF.EQ.1) GO TO 40                                           OPT31880
      WRITE (5,130)                                                     OPT31890
      DO 20 I=1,NS                                                      OPT31900
      DO 10 J=1,NS                                                      OPT31910
      WRITE (5,120) I,J                                                 OPT31920
      CALL RDREAL (ANSR)                                                OPT31930
      BA(I,J)=ANSR                                                      OPT31940
10    CONTINUE                                                          OPT31950
20    CONTINUE                                                          OPT31960
C---------------------------------------------------------------------  OPT31970
30    CALL FRTCMS ('CLRSCRN ')                                          OPT31980
40    CONTINUE                                                          OPT31990
      WRITE (5,140)                                                     OPT32000
      CALL MATPRT (BA,NS,NS)                                            OPT32010
50    WRITE (5,150)                                                     OPT32020
      CALL RDCHAR (IANS)                                                OPT32030
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 60                       OPT32040
      GO TO 70                                                          OPT32050
60    WRITE (5,160)                                                     OPT32060
      GO TO 50                                                          OPT32070
70    CONTINUE                                                          OPT32080
      IF (IANS.EQ.IZ) GO TO 110                                         OPT32090
      IF (IANS.EQ.IY) GO TO 80                                          OPT32100
80    WRITE (5,170)                                                     OPT32110
      CALL RDINT (IANS)                                                 OPT32120
      K=IANS                                                            OPT32130
      WRITE (5,180)                                                     OPT32140
      CALL RDINT (IANS)                                                 OPT32150
      L=IANS                                                            OPT32160
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      WRITE (5,120) K,L                                                 OPT32170
      CALL RDREAL (ANSR)                                                OPT32180
      DUM=ANSR                                                          OPT32190
      DO 100 I=1,NS                                                     OPT32200
      DO 90 J=1,NS                                                      OPT32210
      IF ((I.EQ.K).AND.(J.EQ.L)) BA(I,J)=DUM                            OPT32220
90    CONTINUE                                                          OPT32230
100   CONTINUE                                                          OPT32240
      GO TO 30                                                          OPT32250
110   CONTINUE                                                          OPT32260
      CALL FRTCMS ('CLRSCRN ')                                          OPT32270
      RETURN                                                            OPT32280
C-----------------------------------------------------------------------OPT32290
120   FORMAT (5X,14HTHE ELEMENT F(,I2,1H,,I2,2H)=)                      OPT32300
130   FORMAT (/,5X,36HENTER THE SYSTEM MATRIX  "F"-MATRIX&,//,10X,41HDIMOPT32310
     1ENSION = # STATES  NS& X # STATES  NS&)                           OPT32320
140   FORMAT (//,15X,33HTHE SYSTEM MATRIX  "F"-MATRIX&...,//)           OPT32330
150   FORMAT (//5X,54HDO YOU WISH TO CHANGE THE VALUE OF ANY MATRIX ELEMOPT32340
     1ENT?,//,10X,19HTYPE "YES" OR "NO".)                               OPT32350
160   FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" OR "NO".)OPT32360
170   FORMAT (5X,50HENTER THE ROW NUMBER OF THE ELEMENT TO BE CHANGED.)  OPT32370
180   FORMAT (5X,53HENTER THE COLUMN NUMBER OF THE ELEMENT TO BE CHANGEDOPT32380
     1.)                                                                OPT32390
      END                                                               OPT32400
C=======================================================================OPT32410
      SUBROUTINE READH (NO,NS,ISAH,HO)                                  OPT32420
C     INTERACTIVELY INPUTS THE "H" MATRIX  MEASUREMENT SCALING MATRIX&.=OPT32430
C=======================================================================OPT32440
      REAL*8  HO(NO,NS),DUM,ANSR                                        OPT32450
      INTEGER IANS,I,J,K,L,ISAH                                         OPT32460
      DATA IY/'Y'/,IZ/'N'/                                              OPT32470
C-----------------------------------------------------------------------OPT32480
      IF (ISAH.EQ.1) GO TO 40                                           OPT32490
      WRITE (5,120)                                                     OPT32500
      DO 20 I=1,NO                                                      OPT32510
      DO 10 J=1,NS                                                      OPT32520
      WRITE (5,110) I,J                                                 OPT32530
      CALL RDREAL (ANSR)                                                OPT32540
      HO(I,J)=ANSR                                                      OPT32550
10    CONTINUE                                                          OPT32560
20    CONTINUE                                                          OPT32570
C-----------------------------------------------------------------------OPT32580
30    CALL FRTCMS ('CLRSCRN ')                                          OPT32590
40    CONTINUE                                                          OPT32600
      WRITE (5,130)                                                     OPT32610
      CALL MATPRT (HO,NO,NS)                                            OPT32620
50    WRITE (5,140)                                                     OPT32630
      CALL RDCHAR (IANS)                                                OPT32640
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      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 60                       OPT32650
      GO TO 70                                                          OPT32660
60    WRITE (5,150)                                                     OPT32670
      GO TO 50                                                          OPT32680
70    CONTINUE                                                          OPT32690
      IF (IANS.EQ.IZ) GO TO 100                                         OPT32700
      WRITE (5,160)                                                     OPT32710
      CALL RDINT (IANS)                                                 OPT32720
      K=IANS                                                            OPT32730
      WRITE (5,170)                                                     OPT32740
      CALL RDINT (IANS)                                                 OPT32750
      L=IANS                                                            OPT32760
      WRITE (5,110) K,L                                                 OPT32770
      CALL RDREAL (ANSR)                                                OPT32780
      DUM=ANSR                                                          OPT32790
      DO 90 I=1,NC                                                      OPT32800
      DO 80 J=1,NS                                                      OPT32810
      IF ((I.EQ.K).AND.(J.EQ.L)) HO(I,J)=DUM                            OPT32820
80    CONTINUE                                                          OPT32830
90    CONTINUE                                                          OPT32840
      GO TO 30                                                          OPT32850
100   CONTINUE                                                          OPT32860
      CALL FRTCMS ('CLRSCRN ')                                          OPT32870
      RETURN                                                            OPT32880
C------------------------------------------------------------------------OPT32890
110   FORMAT (5X,14HTHE ELEMENT H(,I2,1H,,I2,2H)=)                      OPT32900
120   FORMAT (/,5X,50HENTER THE MEASUREMENT SCALING MATRIX  "H"-MATRIX&.OPT32910
     1,//,10X,47HDIMENSION = # OBSERVATIONS  NC& X # STATES  NS&)       OPT32920
130   FORMAT (//,10X,46HTHE MEASUREMENT SCALING MATRIX  "H"-MATRIX&...,/OPT32930
     1/)                                                                OPT32940
140   FORMAT (//5X,54HDO YOU WISH TO CHANGE THE VALUE OF ANY MATRIX ELEMOPT32950
     1ENT?,//,10X,19HTYPE "YES" OR "NO".)                               OPT32960
150   FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" OR "NO".)OPT32970
160   FORMAT (5X,50HENTER THE ROW NUMBER OF THE ELEMENT TO BE CHANGED.)  OPT32980
170   FORMAT (5X,52HENTER THE COLUMN NUMBER OF THE ELEMENT TO BE CHANGEDOPT32990
     1)                                                                 OPT33000
      END                                                               OPT33010
C=======================================================================OPT33020
      SUBROUTINE READD (NC,NC,D)                                        OPT33030
C     INPUTS THE "D" MATRIX  MEASUREMENT FEED-FORWARD DIST. MATRIX&.   =OPT33040
C=======================================================================OPT33050
      REAL*8  D(NC,NC),DUM,ANSR                                         OPT33060
      INTEGER IANS,I,J,K,L                                              OPT33070
      DATA IY/'Y'/,IZ/'N'/                                              OPT33080
      WRITE (5,110)                                                     OPT33090
      DO 20 I=1,NC                                                      OPT33100
      DO 10 J=1,NC                                                      OPT33110
      WRITE (5,100) I,J                                                 OPT33120
```

```
      CALL RDREAL (ANSR)                                                    OPT33130
      D(I,J)=ANSR                                                           OPT33140
10    CONTINUE                                                              OPT33150
20    CONTINUE                                                              OPT33160
C-----------------------------------------------------------------------    OPT33170
30    CALL FRTCMS ('CLRSCRN ')                                              OPT33180
      WRITE (5,120)                                                         OPT33190
      CALL MATPRT (D,NO,NC)                                                 OPT33200
40    WRITE (5,130)                                                         OPT33210
      CALL RDCHAR (IANS)                                                    OPT33220
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 50                           OPT33230
      GO TO 60                                                              OPT33240
50    WRITE (5,140)                                                         OPT33250
      GO TO 40                                                              OPT33260
60    CONTINUE                                                              OPT33270
      IF (IANS.EQ.IZ) GO TO 90                                              OPT33280
      WRITE (5,150)                                                         OPT33290
      CALL RDINT (IANS)                                                     OPT33300
      K=IANS                                                                OPT33310
      WRITE (5,160)                                                         OPT33320
      CALL RDINT (IANS)                                                     OPT33330
      L=IANS                                                                OPT33340
      WRITE (5,100) K,L                                                     OPT33350
      CALL RDREAL (ANSR)                                                    OPT33360
      DUM=ANSR                                                              OPT33370
      DO 80 I=1,NC                                                          OPT33380
      DO 70 J=1,NC                                                          OPT33390
      IF ((I.EQ.K).AND.(J.EQ.L)) D(I,J)=DUM                                 OPT33400
70    CONTINUE                                                              OPT33410
80    CONTINUE                                                              OPT33420
      GO TO 30                                                              OPT33430
90    CONTINUE                                                              OPT33440
      CALL FRTCMS ('CLRSCRN ')                                              OPT33450
      RETURN                                                                OPT33460
C-----------------------------------------------------------------------    OPT33470
100   FORMAT (5X,14HTHE ELEMENT D(,I2,1H,,I2,2H)=)                          OPT33480
110   FORMAT (/,5X,54HENTER THE MEASUREMENT FEEDTHROUGH MATRIX / FEEDFOROPT33490
     1WARD,/,5X,34H DISTRIBUTION MATRIX  "D"-MATRIX&.,//,8X,49HDIMENSIONOPT33500
     2 = # OBSERVATIONS  NC& X # CONTROLS  NC&)                          OPT33510
120   FORMAT (//,5X,50HTHE FEEDFORWARD DISTRIBUTION MATRIX  "C"-MATRIX&.OPT33520
     1.,//)                                                             OPT33530
130   FORMAT (//5X,54HDO YOU WISH TO CHANGE THE VALUE OF ANY MATRIX ELEMOPT33540
     1ENT?,//,10X,19HTYPE "YES" OR "NO".)                               OPT33550
140   FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" OR "NO".)OPT33560
150   FORMAT (5X,50HENTER THE ROW NUMBER OF THE ELEMENT TO BE CHANGED.)  OPT33570
160   FORMAT (5X,53HENTER THE COLUMN NUMBER OF THE ELEMENT TO BE CHANGEDOPT33580
     1.)                                                                OPT33590
      END                                                               OPT33600
```

```
C=====================================================================OPT33610
      SUBROUTINE READG (NS,NC,ISAG,G)                                 OPT33620
C     INTERACTIVELY INPUTS THE "G" MATRIX  CONTROL DISTRIBUTION MATRIX&=OPT33630
C=====================================================================OPT33640
      REAL*8  G(NS,NC),DUM,ANSR                                       OPT33650
      INTEGER IANS,I,J,K,L,ISAG                                       OPT33660
      DATA IY/'Y'/,IZ/'N'/                                            OPT33670
      IF (ISAG.EQ.1) GO TO 40                                         OPT33680
      WRITE (5,120)                                                   OPT33690
      DO 20 I=1,NS                                                    OPT33700
      DO 10 J=1,NC                                                    OPT33710
      WRITE (5,110) I,J                                               OPT33720
      CALL RDREAL (ANSR)                                              OPT33730
      G(I,J)=ANSR                                                     OPT33740
10    CONTINUE                                                        OPT33750
20    CONTINUE                                                        OPT33760
C---------------------------------------------------------------------OPT33770
30    CALL FRTCMS ('CLRSCRN ')                                        OPT33780
40    CONTINUE                                                        OPT33790
      WRITE (5,130)                                                   OPT33800
      CALL MATPRT (G,NS,NC)                                           OPT33810
50    WRITE (5,140)                                                   OPT33820
      CALL RDCHAR (IANS)                                              OPT33830
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 60                     OPT33840
      GO TO 70                                                        OPT33850
60    WRITE (5,150)                                                   OPT33860
      GO TO 50                                                        OPT33870
70    CONTINUE                                                        OPT33880
      IF (IANS.EQ.IZ) GO TO 100                                       OPT33890
      WRITE (5,160)                                                   OPT33900
      CALL RDINT (IANS)                                               OPT33910
      K=IANS                                                          OPT33920
      WRITE (5,170)                                                   OPT33930
      CALL RDINT (IANS)                                               OPT33940
      L=IANS                                                          OPT33950
      WRITE (5,110) K,L                                               OPT33960
      CALL RDREAL (ANSR)                                              OPT33970
      DUM=ANSR                                                        OPT33980
      DO 90 I=1,NS                                                    OPT33990
      DO 80 J=1,NC                                                    OPT34000
      IF ((I.EQ.K).AND.(J.EQ.L)) G(I,J)=DUM                           OPT34010
80    CONTINUE                                                        OPT34020
90    CONTINUE                                                        OPT34030
      GO TO 30                                                        OPT34040
100   CONTINUE                                                        OPT34050
      CALL FRTCMS ('CLRSCRN ')                                        OPT34060
      RETURN                                                          OPT34070
C---------------------------------------------------------------------OPT34080
```

```
110    FORMAT (5X,14HTHE ELEMENT G(,I2,1H,,I2,2H)=)                          OPT34090
120    FORMAT (/,5X,51HENTER THE CONTROL DISTRIBUTION MATRIX  "G"-MATRIX&OPT34100
      1o,//,10X,42HDIMENSION = # STATES  NS& X # CONTRCLS  NC&)             OPT34110
130    FORMAT (//,10X,47HTHE CONTROL DISTRIBUTION MATRIX  "G"-MATRIX&...,OPT34120
      1//)                                                                  OPT34130
140    FORMAT (//5X,54HDO YCU WISH TO CHANGE THE VALUE CF ANY MATRIX ELEMOPT34140
      1ENT?,//,10X,19HTYPE "YES" OR "NO".)                                  OPT34150
150    FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" CR "NO".)OPT34160
160    FORMAT (5X,52HENTER THE ROW NUMBER OF THE ELEMENT TC BE CHANGED.)  OPT34170
170    FORMAT (5X,53HENTER THE COLUMN NUMBER OF THE ELEMENT TO BE CHANGEDOPT34180
      1o)                                                                   OPT34190
       END                                                                  OPT34200
C=====================================================================OPT34210
       SUBROUTINE READFB (NC,NS,FBGC)                                       OPT34220
C      INPUTS THE "C"     FEEDBACK GAIN CONTROL MATRIX&.                 =OPT34230
C=====================================================================OPT34240
       REAL*8  FBGC(NC,NS),DUM,ANSR                                         OPT34250
       INTEGER IANS,I,J,K,L                                                 OPT34260
       DATA IY/'Y'/,IZ/'N'/                                                 OPT34270
       WRITE (5,110)                                                        OPT34280
       DO 20 I=1,NC                                                         OPT34290
       DO 10 J=1,NS                                                         OPT34300
       WRITE (5,100) I,J                                                    OPT34310
       CALL RDREAL (ANSR)                                                   OPT34320
       FBGC(I,J)=ANSR                                                       OPT34330
10     CONTINUE                                                             OPT34340
20     CONTINUE                                                             OPT34350
C---------------------------------------------------------------------OPT34360
30     CALL FRTCMS ('CLRSCRN ')                                             OPT34370
       WRITE (5,120)                                                        OPT34380
       CALL MATPRT (FBGC,NC,NS)                                             OPT34390
40     WRITE (5,120)                                                        OPT34400
       CALL RDCHAR (IANS)                                                   OPT34410
       IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 50                          OPT34420
       GO TO 60                                                             OPT34430
50     WRITE (5,140)                                                        OPT34440
       GO TO 40                                                             OPT34450
60     CONTINUE                                                             OPT34460
       IF (IANS.EQ.IZ) GO TO 90                                             OPT34470
       WRITE (5,150)                                                        OPT34480
       CALL RDINT (IANS)                                                    OPT34490
       K=IANS                                                               OPT34500
       WRITE (5,160)                                                        OPT34510
       CALL RDINT (IANS)                                                    OPT34520
       L=IANS                                                               OPT34530
       WRITE (5,100) K,L                                                    OPT34540
       CALL RDREAL (ANSR)                                                   OPT34550
       DUM=ANSR                                                             OPT34560
```

```
      DO 80 I=1,NC                                                          OPT34570
      DO 70 J=1,NS                                                          OPT34580
      IF ((I.EQ.K).AND.(J.EQ.L)) FBGC(I,J)=DUM                              OPT34590
 7C   CONTINUE                                                             OPT34600
 8C   CONTINUE                                                             OPT34610
      GO TO 30                                                              OPT34620
 9C   CONTINUE                                                             OPT34630
      CALL FRTCMS ('CLRSCRN ')                                              OPT34640
      RETURN                                                                OPT34650
C-------------------------------------------------------------------------- OPT34660
100   FORMAT (5X,14HTHE ELEMENT C(,I2,1H,,I2,2H)=)                          OPT34670
110   FORMAT (/,5X,52HENTER THE FEEDBACK GAIN CONTROL MATRIX  "C"-MATRIXOPT34680
     1&.,//,10X,44HDIMENSION = # CONTROLS  NC& X # STATES  NS&.)          OPT34690
120   FORMAT (//,10X,45HTHE FEEDBACK GAIN CONTROL MATRIX  "C"-MATRIX&,//OPT34700
     1)                                                                     OPT34710
130   FORMAT (//5X,54HDO YOU WISH TO CHANGE THE VALUE OF ANY MATRIX ELEMOPT34720
     1ENT?,//,10X,19HTYPE "YES" OR "NO".)                                   OPT34730
140   FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" OR "NO".)OPT34740
150   FORMAT (5X,5CHENTER THE ROW NUMBER OF THE ELEMENT TO BE CHANGED.)  OPT34750
160   FORMAT (5X,53HENTER THE COLUMN NUMBER OF THE ELEMENT TO BE CHANGEDOPT34760
     1.)                                                                    OPT34770
      END                                                                   OPT34780
C=========================================================================OPT34790
      SUBROUTINE READAY (NC,ISAA,AY)                                        OPT34800
C     INPUTS THE "A" MATRIX   DIAGONAL OUTPUT COST MATRIX&.              =OPT34810
C=========================================================================OPT34820
      REAL*8  AY(NC,NC),DUM,ANSR                                            OPT34830
      INTEGER IANS,I,J,K,L                                                  OPT34840
      DATA IY/'Y'/,IZ/'N'/                                                  OPT34850
      IF (ISAA.EQ.1) GO TO 30                                               OPT34860
      WRITE (5,110)                                                         OPT34870
      DO 20 I=1,NC                                                          OPT34880
      DO 10 J=1,NC                                                          OPT34890
      WRITE (5,100) I,J                                                     OPT34900
      CALL RDREAL (ANSR)                                                    OPT34910
      AY(I,J)=ANSR                                                          OPT34920
 1C   CONTINUE                                                             OPT34930
 2C   CONTINUE                                                             OPT34940
C-------------------------------------------------------------------------OPT34950
 3C   CALL FRTCMS ('CLRSCRN ')                                             OPT34960
      WRITE (5,120)                                                         OPT34970
      CALL MATPRT (AY,NC,NC)                                                OPT34980
 4C   WRITE (5,130)                                                        OPT34990
      CALL RDCHAR (IANS)                                                    OPT35000
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 50                           OPT35010
      GO TO 60                                                              OPT35020
 5C   WRITE (5,140)                                                        OPT35030
      GO TO 40                                                              OPT35040
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```
60    CONTINUE                                                          OPT35050
      IF (IANS.EQ.IZ) GO TO 90                                          OPT35060
      WRITE (5,150)                                                     OPT35070
      CALL RDINT (IANS)                                                 OPT35080
      K=IANS                                                            OPT35090
      WRITE (5,160)                                                     OPT35100
      CALL RDINT (IANS)                                                 OPT35110
      L=IANS                                                            OPT35120
      WRITE (5,100) K,L                                                 OPT35130
      CALL RDREAL (ANSR)                                                OPT35140
      DUM=ANSR                                                          OPT35150
      DO 80 I=1,NC                                                      OPT35160
      DO 70 J=1,NC                                                      OPT35170
      IF ((I.EQ.K).AND.(J.EQ.L)) AY(I,J)=DUM                            OPT35180
70    CONTINUE                                                          OPT35190
80    CONTINUE                                                          OPT35200
      GO TO 30                                                          OPT35210
90    CONTINUE                                                          OPT35220
      CALL FRTCMS ('CLRSCRN ')                                          OPT35230
      RETURN                                                            OPT35240
C-----------------------------------------------------------------------OPT35250
100   FORMAT (5X,14HTHE ELEMENT A(,I2,1H,,I2,2H)=)                      OPT35260
110   FORMAT (//,5X,54HENTER THE OUTPUT MEASUREMENT COST MATRIX  "A"-MATOPT35270
     1RIX&.,/,5X,53HDIMENSION = # OBSERVATIONS  NO& X # OBSERVATIONS  NOOPT35280
     2&)                                                                OPT35290
120   FORMAT (//,5X,50HTHE OUTPUT MEASUREMENT COST MATRIX  "A"-MATRIX&.OPT35300
     1.,//)                                                            OPT35310
130   FORMAT (//5X,54HDO YOU WISH TO CHANGE THE VALUE OF ANY MATRIX ELEMOPT35320
     1ENT?,//,10X,19HTYPE "YES" OR "NO".)                              OPT35330
140   FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" OR "NO".)OPT35340
150   FORMAT (5X,50HENTER THE ROW NUMBER OF THE ELEMENT TO BE CHANGED.) OPT35350
160   FORMAT (5X,53HENTER THE COLUMN NUMBER OF THE ELEMENT TO BE CHANGEDOPT35360
     1.)                                                               OPT35370
      END                                                               OPT35380
C=======================================================================OPT35390
      SUBROUTINE READB (NC,ISAB,B)                                      OPT35400
C     INPUTS THE "B" MATRIX  CONTROL COST WEIGHTING MATRIX&.          =OPT35410
C=======================================================================OPT35420
      REAL*8  B(NC,NC),DUM,ANSR                                         OPT35430
      INTEGER IANS,I,J,K,L                                              OPT35440
      DATA IY/'Y'/,IZ/'N'/                                              OPT35450
      IF (ISAB.EQ.1) GO TO 20                                           OPT35460
      WRITE (5,90)                                                      OPT35470
      DO 10 I=1,NC                                                      OPT35480
      DO 10 J=1,NC                                                      OPT35490
      WRITE (5,80) I,J                                                  OPT35500
      CALL RDREAL (ANSR)                                                OPT35510
10    B(I,J)=ANSR                                                       OPT35520
```

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C-----------------------------------------------------------------------OPT35530
20    CALL FRTCMS ('CLRSCRN ')                                          OPT35540
      WRITE (5,100)                                                     OPT35550
      CALL MATPRT (B,NC,NC)                                             OPT35560
30    WRITE (5,110)                                                     OPT35570
      CALL RDCHAR (IANS)                                                OPT35580
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 40                       OPT35590
      GO TO 50                                                          OPT35600
40    WRITE (5,120)                                                     OPT35610
      GO TO 30                                                          OPT35620
50    CONTINUE                                                          OPT35630
      IF (IANS.EQ.IZ) GO TO 70                                          OPT35640
      WRITE (5,130)                                                     OPT35650
      CALL RDINT (IANS)                                                 OPT35660
      K=IANS                                                            OPT35670
      WRITE (5,140)                                                     OPT35680
      CALL RDINT (IANS)                                                 OPT35690
      L=IANS                                                            OPT35700
      WRITE (5,80) K,L                                                  OPT35710
      CALL RDREAL (ANSR)                                                OPT35720
      DUM=ANSR                                                          OPT35730
      DO 60 I=1,NC                                                      OPT35740
      DO 60 J=1,NC                                                      OPT35750
      IF ((I.EQ.K).AND.(J.EQ.L)) B(I,J)=DUM                             OPT35760
60    CONTINUE                                                          OPT35770
      GO TO 20                                                          OPT35780
70    CONTINUE                                                          OPT35790
      CALL FRTCMS ('CLRSCRN ')                                          OPT35800
      RETURN                                                            OPT35810
C-----------------------------------------------------------------------OPT35820
80    FORMAT (5X,14HTHE ELEMENT B(,I2,1H,,I2,2H)=)                      OPT35830
90    FORMAT (/,5X,52HENTER THE CONTROL COST WEIGHTING MATRIX  "B"-MATRIOPT35840
     1X&,/,10X,45HDIMENSION = # CONTROLS  NC& X # CONTROLS  NC&)         OPT35850
100   FORMAT (//,10X,37HTHE CONTROL COST MATRIX.........B...,//)        OPT35860
110   FORMAT (//5X,54HDO YOU WISH TO CHANGE THE VALUE OF ANY MATRIX ELEMOPT35870
     1ENT?,//,10X,19HTYPE "YES" OR "NO".)                               OPT35880
120   FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" OR "NO".)OPT35890
130   FORMAT (5X,50HENTER THE ROW NUMBER OF THE ELEMENT TO BE CHANGED.) OPT35900
140   FORMAT (5X,52HENTER THE COLUMN NUMBER OF THE ELEMENT TO BE CHANGEDOPT35910
     1)                                                                 OPT35920
      END                                                               OPT35930
C=======================================================================OPT35940
      SUBROUTINE READG2 (NS,NG,IGAM,GAM)                                OPT35950
C     INPUTS THE "GAM" MATRIX  PROCESS NOISE DISTRIBUTION MATRIX&.     =OPT35960
C=======================================================================OPT35970
      REAL*8  GAM(NS,NG),DUM,ANSR                                       OPT35980
      INTEGER IANS,I,J,K,L,IGAM                                         OPT35990
      DATA IY/'Y'/,IZ/'N'/                                              OPT36000
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      IF (IGAM.EQ.1) GO TO 40                                          OPT36010
      WRITE (5,120)                                                    OPT36020
      DO 20 I=1,NS                                                     OPT36030
      DO 10 J=1,NG                                                     OPT36040
      WRITE (5,110) I,J                                                OPT36050
      CALL RDREAL (ANSR)                                               OPT36060
      GAM(I,J)=ANSR                                                    OPT36070
10    CONTINUE                                                         OPT36080
20    CONTINUE                                                         OPT36090
C-----------------------------------------------------------------------OPT36100
30    CALL FRTCMS ('CLRSCRN ')                                         OPT36110
40    CONTINUE                                                         OPT36120
      WRITE (5,130)                                                    OPT36130
      CALL MATPRT (GAM,NS,NG)                                          OPT36140
50    WRITE (5,140)                                                    OPT36150
      CALL RDCHAR (IANS)                                               OPT36160
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 60                      OPT36170
      GO TO 70                                                         OPT36180
60    WRITE (5,150)                                                    OPT36190
      GO TO 50                                                         OPT36200
70    CONTINUE                                                         OPT36210
      IF (IANS.EQ.IZ) GO TO 100                                        OPT36220
      WRITE (5,160)                                                    OPT36230
      CALL RDINT (IANS)                                                OPT36240
      K=IANS                                                           OPT36250
      WRITE (5,170)                                                    OPT36260
      CALL RDINT (IANS)                                                OPT36270
      L=IANS                                                           OPT36280
      WRITE (5,110) K,L                                                OPT36290
      CALL RDREAL (ANSR)                                               OPT36300
      DUM=ANSR                                                         OPT36310
      DO 90 I=1,NS                                                     OPT36320
      DO 80 J=1,NG                                                     OPT36330
      IF ((I.EQ.K).AND.(J.EQ.L)) GAM(I,J)=DUM                          OPT36340
80    CONTINUE                                                         OPT36350
90    CONTINUE                                                         OPT36360
      GO TO 30                                                         OPT36370
100   CONTINUE                                                         OPT36380
      CALL FRTCMS ('CLRSCRN ')                                         OPT36390
      RETURN                                                           OPT36400
C-----------------------------------------------------------------------OPT36410
110   FORMAT (5X,16HTHE ELEMENT GAM(,I2,1H,,I2,2H)=)                   OPT36420
120   FORMAT (/,5X,36HENTER THE PROCESS NOISE DISTRIBUTION,/,5X,24HMATRIOPT36430
     1X  "GAMMA"-MATRIX&.,/,2X,56HDIMENSION = # STATES  NS& X # PROCESS OPT36440
     2NOISE SOURCES  NG&)                                              OPT36450
130   FORMAT (//,10X,37HTHE PROCESS NOISE DISTRIBUTION MATRIX,/,10X,19H OPT36460
     1"GAMMA"-MATRIX&...,//)                                           OPT36470
140   FORMAT (//5X,54HDO YOU WISH TO CHANGE THE VALUE OF ANY MATRIX ELEMOPT36480
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     1ENT?,//,10X,19HTYPE "YES" OR "NO".)                                    OPT36490
150   FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" OR "NO".)OPT36500
160   FORMAT (5X,50HENTER THE ROW NUMBER OF THE ELEMENT TO BE CHANGED.) OPT36510
170   FORMAT (5X,53HENTER THE COLUMN NUMBER OF THE ELEMENT TO BE CHANGEDOPT36520
     1.)                                                                     OPT36530
      END                                                                    OPT36540
C=====================================================================OPT36550
      SUBROUTINE READQ (NG,Q)                                                OPT36560
C     INTERACTIVELY INPUTS THE "Q" MATRIX  NOISE WEIGHTING MATRIX&     =OPT36570
C=====================================================================OPT36580
      REAL*8  Q(NG,NG),DUM,ANSR                                              OPT36590
      INTEGER IANS,I,J,K,L                                                   OPT36600
      DATA IY/'Y'/,IZ/'N'/                                                   OPT36610
      WRITE (5,110)                                                          OPT36620
      DO 20 I=1,NG                                                           OPT36630
      DO 10 J=1,NG                                                           OPT36640
      WRITE (5,100) I,J                                                      OPT36650
      CALL RDREAL (ANSR)                                                     OPT36660
      Q(I,J)=ANSR                                                            OPT36670
10    CONTINUE                                                               OPT36680
20    CONTINUE                                                               OPT36690
C---------------------------------------------------------------------OPT36700
30    CALL FRTCMS ('CLRSCRN ')                                               OPT36710
      WRITE (5,120)                                                          OPT36720
      CALL MATPRT (Q,NG,NG)                                                  OPT36730
40    WRITE (5,130)                                                          OPT36740
      CALL RDCHAR (IANS)                                                     OPT36750
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 50                            OPT36760
      GO TO 60                                                               OPT36770
50    WRITE (5,140)                                                          OPT36780
      GO TO 40                                                               OPT36790
60    CONTINUE                                                               OPT36800
      IF (IANS.EQ.IZ) GO TO 90                                               OPT36810
      WRITE (5,150)                                                          OPT36820
      CALL RDINT (IANS)                                                      OPT36830
      K=IANS                                                                 OPT36840
      WRITE (5,160)                                                          OPT36850
      CALL RDINT (IANS)                                                      OPT36860
      L=IANS                                                                 OPT36870
      WRITE (5,100) K,L                                                      OPT36880
      CALL RDREAL (ANSR)                                                     OPT36890
      DUM=ANSR                                                               OPT36900
      DO 80 I=1,NG                                                           OPT36910
      DO 70 J=1,NG                                                           OPT36920
      IF ((I.EQ.K).AND.(J.EQ.L)) Q(I,J)=DUM                                  OPT36930
70    CONTINUE                                                               OPT36940
80    CONTINUE                                                               OPT36950
      GO TO 30                                                               OPT36960
```

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 90    CONTINUE                                                          OPT36970
       CALL FRTCMS ('CLRSCRN ')                                          OPT36980
       RETURN                                                            OPT36990
C------------------------------------------------------------------------ OPT37000
100    FORMAT (5X,14HTHE ELEMENT Q(,I2,1H,,I2,2H)=)                      OPT37010
110    FORMAT (//,5X,44HENTER THE PROCESS NOISE PSD WEIGHTING MATRIX,/,5XOPT37020
      1,12H "Q"MATRIX&.,//,5X,42HDIMENSION = # PROCESS NOISE SOURCES  NG&OPT37030
      2 X,/,17X,27H=#PROCESS NOISE SOURCES  NG&)                         OPT37040
120    FORMAT (//,5X,42HTHE PROCESS NOISE WEIGHTING MATRIX.....Q...,//)  OPT37050
130    FORMAT (//5X,54HDO YOU WISH TO CHANGE THE VALUE OF ANY MATRIX ELEMOPT37060
      1ENT?,//,10X,19HTYPE "YES" OR "NO".)                               OPT37070
140    FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" OR "NO".)OPT37080
150    FORMAT (5X,50HENTER THE ROW NUMBER OF THE ELEMENT TO BE CHANGED.)  OPT37090
160    FORMAT (5X,53HENTER THE COLUMN NUMBER OF THE ELEMENT TO BE CHANGEDOPT37100
      1.)                                                                OPT37110
       END                                                               OPT37120
C=======================================================================OPT37130
       SUBROUTINE READR (NO,RC)                                          OPT37140
C      INTERACTIVELY INPUTS THE "R" MATRIX=                              OPT37150
C       MEASUREMENT NOISE DISTRIBUTION MATRIX.&                         =OPT37160
C=======================================================================OPT37170
       REAL*8  RC(NO,NO),DUM,ANSR                                        OPT37180
       INTEGER IANS,I,J,K,L                                              OPT37190
       DATA IY/'Y'/,IZ/'N'/                                              OPT37200
       WRITE (5,90)                                                      OPT37210
       DO 10 I=1,NO                                                      OPT37220
       DO 10 J=1,NO                                                      OPT37230
       WRITE (5,80) I,J                                                  OPT37240
       CALL RDREAL (ANSR)                                                OPT37250
 10    RC(I,J)=ANSR                                                      OPT37260
C------------------------------------------------------------------------OPT37270
 20    CALL FRTCMS ('CLRSCRN ')                                          OPT37280
       WRITE (5,100)                                                     OPT37290
       CALL MATPRT (RC,NO,NO)                                            OPT37300
 30    WRITE (5,110)                                                     OPT37310
       CALL RDCHAR (IANS)                                                OPT37320
       IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 40                       OPT37330
       GO TO 50                                                          OPT37340
 40    WRITE (5,120)                                                     OPT37350
       GO TO 30                                                          OPT37360
 50    CONTINUE                                                          OPT37370
       IF (IANS.EQ.IZ) GO TO 70                                          OPT37380
       WRITE (5,130)                                                     OPT37390
       CALL RDINT (IANS)                                                 OPT37400
       K=IANS                                                            OPT37410
       WRITE (5,140)                                                     OPT37420
       CALL RDINT (IANS)                                                 OPT37430
       L=IANS                                                            OPT37440
```

```
      WRITE (5,80) K,L                                                  OPT37450
      CALL RDREAL (ANSR)                                                OPT37460
      DUM=ANSR                                                          OPT37470
      DO 60 I=1,NC                                                      OPT37480
      DO 60 J=1,NC                                                      OPT37490
60    IF ((I.EQ.K).AND.(J.EQ.L)) RC(I,J)=DUM                            OPT37500
      GO TO 20                                                          OPT37510
70    CONTINUE                                                          OPT37520
      CALL FRTCMS ('CLRSCRN ')                                          OPT37530
      RETURN                                                            OPT37540
C-----------------------------------------------------------------------OPT37550
80    FORMAT (5X,14HTHE ELEMENT R(,I2,1H,,I2,2H)=)                      OPT37560
90    FORMAT (/,5X,60HENTER THE MEASUREMENT NOISE DISTRIBUTION MATRIX  "OPT37570
     1R"MATRIX&. ,//,5X,53HDIMENSION = # OBSERVATIONS  NO& X # OBSERVATIOPT37580
     2NS  NO&)                                                          OPT37590
100   FORMAT (//,15X,50HTHE MEASUREMENT NOISE DISTRIBUTION MATRIX.....R.OPT37600
     1..,//)                                                            OPT37610
110   FORMAT (//5X,54HDO YOU WISH TO CHANGE THE VALUE OF ANY MATRIX ELEMOPT37620
     1ENT?,//,10X,19HTYPE "YES" OR "NO".)                               OPT37630
120   FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" OR "NO".)OPT37640
130   FORMAT (5X,50HENTER THE ROW NUMBER OF THE ELEMENT TO BE CHANGED.) OPT37650
140   FORMAT (5X,52HENTER THE COLUMN NUMBER OF THE ELEMENT TO BE CHANGEDOPT37660
     1)                                                                 OPT37670
      END                                                               OPT37680
C=======================================================================OPT37690
      SUBROUTINE READFE (NS,NO,FBGE)                                    OPT37700
C     INTERACTIVELY INPUTS THE "K"  FEEDBACK GAIN ESTIMATOR MATRIX&    =OPT37710
C=======================================================================OPT37720
      REAL*8  FBGE(NS,NO),DUM,ANSR                                      OPT37730
      INTEGER IANS,I,J,K,L                                              OPT37740
      DATA IY/'Y'/,IZ/'N'/                                              OPT37750
      WRITE (5,110)                                                     OPT37760
      DO 20 I=1,NS                                                      OPT37770
      DO 10 J=1,NO                                                      OPT37780
      WRITE (5,100) I,J                                                 OPT37790
      CALL RDREAL (ANSR)                                                OPT37800
      FBGE(I,J)=ANSR                                                    OPT37810
10    CONTINUE                                                          OPT37820
20    CONTINUE                                                          OPT37830
C-----------------------------------------------------------------------OPT37840
30    CALL FRTCMS ('CLRSCRN ')                                          OPT37850
      WRITE (5,120)                                                     OPT37860
      CALL MATPRT (FBGE,NS,NO)                                          OPT37870
40    WRITE (5,130)                                                     OPT37880
      CALL RDCHAR (IANS)                                                OPT37890
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 50                       OPT37900
      GO TO 40                                                          OPT37910
50    WRITE (5,140)                                                     OPT37920
```

```
      GO TO 40                                                          OPT37930
60    CONTINUE                                                          OPT37940
      IF (IANS.EQ.IZ) GO TO 90                                          OPT37950
      WRITE (5,150)                                                     OPT37960
      CALL RDINT (IANS)                                                 OPT37970
      K=IANS                                                            OPT37980
      WRITE (5,160)                                                     OPT37990
      CALL RDINT (IANS)                                                 OPT38000
      L=IANS                                                            OPT38010
      WRITE (5,100) K,L                                                 OPT38020
      CALL RDREAL (ANSR)                                                OPT38030
      DUM=ANSR                                                          OPT38040
      DO 80 I=1,NS                                                      OPT38050
      DO 70 J=1,NC                                                      OPT38060
      IF ((I.EQ.K).AND.(J.EQ.L)) FBGE(I,J)=DUM                          OPT38070
70    CONTINUE                                                          OPT38080
80    CONTINUE                                                          OPT38090
      GO TO 30                                                          OPT38100
90    CONTINUE                                                          OPT38110
      CALL FRTCMS ('CLRSCRN ')                                          OPT38120
      RETURN                                                            OPT38130
C-----------------------------------------------------------------------  OPT38140
100   FORMAT (5X,14HTHE ELEMENT K(,I2,1H,,I2,2H)=)                      OPT38150
110   FORMAT (/,5X,54HENTER THE FEEDBACK GAIN ESTIMATOR MATRIX  "K"-MATROPT38160
     1IX&.,//,10X,48HDIMENSION = # STATES  NS& X # OBSERVATIONS  NC&.)  OPT38170
120   FORMAT (//,15X,47HTHE FEEDBACK GAIN ESTIMATOR MATRIX  "K"-MATRIX&,OPT38180
     1//)                                                               OPT38190
130   FORMAT (//,5X,54HDO YOU WISH TO CHANGE THE VALUE OF ANY MATRIX ELEOPT38200
     1MENT?,//,10X,19HTYPE "YES" OR "NO".)                              OPT38210
140   FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" OR "NO".)OPT38220
150   FORMAT (5X,50HENTER THE ROW NUMBER OF THE ELEMENT TO BE CHANGED.)  OPT38230
160   FORMAT (5X,52HENTER THE COLUMN NUMBER OF THE ELEMENT TO BE CHANGEDOPT38240
     1)                                                                 OPT38250
      END                                                               OPT38260
C=======================================================================  OPT38270
      SUBROUTINE READW (NG,WR)                                          OPT38280
C     INTERACTIVELY INPUTS THE "WO" MATRIX  STEADY DISTURBANCE VECTOR =  OPT38290
C     MATRIX& ELEMENT BY ELEMENT.                                    =  OPT38300
C=======================================================================  OPT38310
      REAL*8  WR(NG),DUM,ANSR                                           OPT38320
      INTEGER IANS,I,K                                                  OPT38330
      DATA IY/'Y'/,IZ/'N'/                                              OPT38340
      WRITE (5,100)                                                     OPT38350
      DO 10 I=1,NG                                                      OPT38360
      WRITE (5,80) I                                                    OPT38370
      CALL RDREAL (ANSR)                                                OPT38380
      WR(I)=ANSR                                                        OPT38390
10    CONTINUE                                                          OPT38400
```

```
C-------------------------------------------------------------------------OPT38410
20    CALL FRTCMS ('CLRSCRN ')                                             OPT38420
      WRITE (5,110)                                                        OPT38430
      WRITE (5,90) (WR(I),I=1,NG)                                          OPT38440
30    WRITE (5,120)                                                        OPT38450
      CALL RDCHAR (IANS)                                                   OPT38460
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 40                          OPT38470
      GO TO 50                                                             OPT38480
40    WRITE (5,130)                                                        OPT38490
      GO TO 30                                                             OPT38500
50    CONTINUE                                                             OPT38510
      IF (IANS.EQ.IZ) GO TO 70                                             OPT38520
      WRITE (5,140)                                                        OPT38530
      CALL RDINT (IANS)                                                    OPT38540
      K=IANS                                                               OPT38550
      WRITE (5,80) K                                                       OPT38560
      CALL RDREAL (ANSR)                                                   OPT38570
      DUM=ANSR                                                             OPT38580
      DO 60 I=1,NG                                                         OPT38590
      IF (I.EQ.K) WR(I)=DUM                                                OPT38600
60    CONTINUE                                                             OPT38610
      GO TO 20                                                             OPT38620
70    CONTINUE                                                             OPT38630
      CALL FRTCMS ('CLRSCRN ')                                             OPT38640
      RETURN                                                               OPT38650
C-------------------------------------------------------------------------- OPT38660
80    FORMAT (5X,15HTHE ELEMENT WO(,I2,2H)=)                               OPT38670
90    FORMAT (F12.5)                                                       OPT38680
100   FORMAT (/,5X,57HENTER THE STEADY DISTURBANCE VECTOR MATRIX  "WO"-MOPT38690
     1ATRIX&.,//,10X,44HDIMENSION = # PROCESS NOISE SOURCES  NG& X 1)    OPT38700
110   FORMAT (//,15X,53HTHE STEADY DISTURBANCE VECTOR MATRIX  "WO"-MATRIOPT38710
     1X&....,//)                                                          OPT38720
120   FORMAT (//5X,54HDO YOU WISH TO CHANGE THE VALUE OF ANY MATRIX ELEMOPT38730
     1ENT?,//,10X,19HTYPE "YES" OR "NO".)                                 OPT38740
130   FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" OR "NO".)OPT38750
140   FORMAT (5X,50HENTER THE ROW NUMBER OF THE ELEMENT TO BE CHANGED.)    OPT38760
      END                                                                  OPT38770
C=========================================================================OPT38780
C  SUBROUTINE RDREAL -- INTERACTIVELY READS A REAL NUMBER REPLY          =OPT38790
C  INTO A FORTRAN PROGRAM.  IF THE USER INADVERTENLY ENTERS  A NULL      =OPT38800
C  STRING THE S/R ISSUES A WARNING AND ALLOWS A RECOVERY.                =OPT38810
C=========================================================================OPT38820
      SUBROUTINE RDREAL (ANSR)                                             OPT38830
      REAL*8 ANSR                                                          OPT38840
      INTEGER COUNT                                                        OPT38850
C-------------------------------------------------------------------------OPT38860
      COUNT=0                                                              OPT38870
10    CONTINUE                                                             OPT38880
```

```
      COUNT=COUNT+1                                                      OPT38890
      IF (COUNT.LT.3) GO TO 20                                           OPT38900
      WRITE (5,60)                                                       OPT38910
      GO TO 40                                                           OPT38920
20    CONTINUE                                                           OPT38930
      READ (5,*,END=30,ERR=30) ANSR                                      OPT38940
      RETURN                                                             OPT38950
30    REWIND 5                                                           OPT38960
      WRITE (5,50)                                                       OPT38970
      GO TO 10                                                           OPT38980
40    CONTINUE                                                           OPT38990
      STOP                                                               OPT39000
C-----------------------------------------------------------------------OPT39010
50    FORMAT (1X,64HWARNING:  NULL STRINGS ARE NOT ALLOWED, ENTER A NUMEOPT39020
     1RICAL VALUE.)                                                      OPT39030
60    FORMAT (///,5X,47HPROGRAM TERMINATION - TWO NULL STRINGS ENTERED )OPT39040
      END                                                                OPT39050
C=======================================================================OPT39060
C  SUBROUTINE RDINT -- INTERACTIVELY READS AN INTEGER REPLY             =OPT39070
C  INTO A FORTRAN PROGRAM.  IF THE USER INADVERTENLY ENTERS AN IMPROPER=OPT39080
C  DATA CHARACTER THE S/R ISSUES A WARNING AND ALLOWS A RECOVERY.       =OPT39090
C=======================================================================OPT39100
      SUBROUTINE RDINT (IANS)                                            OPT39110
      INTEGER COUNT,IANS                                                 OPT39120
C-----------------------------------------------------------------------OPT39130
      COUNT=0                                                            OPT39140
10    CONTINUE                                                           OPT39150
      COUNT=COUNT+1                                                      OPT39160
      IF (COUNT.LT.3) GO TO 20                                           OPT39170
      WRITE (5,60)                                                       OPT39180
      GO TO 50                                                           OPT39190
20    CONTINUE                                                           OPT39200
      READ (5,*,END=40,ERR=40) IANS                                      OPT39210
      IF (IANS) 40,40,30                                                 OPT39220
30    CONTINUE                                                           OPT39230
      RETURN                                                             OPT39240
40    REWIND 5                                                           OPT39250
      WRITE (5,70)                                                       OPT39260
      GO TO 10                                                           OPT39270
50    CONTINUE                                                           OPT39280
      STOP                                                               OPT39290
C-----------------------------------------------------------------------OPT39300
60    FORMAT (//,5X,49HPROGRAM TERMINATION - TWO IMPROPER DATA ENTRIES   OPT39310
     1)                                                                  OPT39320
70    FORMAT (1X,56HWARNING: IMPROPER DATA ENTRY   ENTER A POSITIVE INTEOPT39330
     1GER.)                                                              OPT39340
      END                                                                OPT39350
C=======================================================================OPT39360
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C  SUBROUTINE RDCHAR -- INTERACTIVELY READS A CHARACTER STRING REPLY   =OPT39370
C  ('YES' OR 'NO') INTO A FORTRAN PROGRAM. IF THE USER INADVERTENLY    =OPT39380
C  ENTERS  A NULL STRING THE S/R ISSUES A WARNING AND ALLOWS A RECOVERY=OPT39390
C=====================================================================OPT39400
      SUBROUTINE RDCHAR (IANS)                                         OPT39410
      INTEGER COUNT,IANS                                               OPT39420
C     DATA IY/'Y'/,IZ/'N'/                                             OPT39430
C---------------------------------------------------------------------OPT39440
      COUNT=0                                                          OPT39450
10    CONTINUE                                                         OPT39460
      COUNT=COUNT+1                                                    OPT39470
      IF (COUNT.LT.3) GO TO 20                                         OPT39480
      WRITE (5,60)                                                     OPT39490
      GO TO 40                                                         OPT39500
20    CONTINUE                                                         OPT39510
      REWIND 5                                                         OPT39520
      READ (5,70,END=30,ERR=30) IANS                                   OPT39530
      RETURN                                                           OPT39540
30    REWIND 5                                                         OPT39550
      WRITE (5,50)                                                     OPT39560
      GO TO 10                                                         OPT39570
40    CONTINUE                                                         OPT39580
      STOP                                                             OPT39590
C---------------------------------------------------------------------OPT39600
50    FORMAT (1X,60HWARNING:  NULL STRINGS ARE NOT ALLOWED, ENTER "YES" OPT39610
     1OR "NO".)                                                        OPT39620
60    FORMAT (///,5X,47HPROGRAM TERMINATION - TWO NULL STRINGS ENTERED )OPT39630
70    FORMAT (A1)                                                      OPT39640
      END                                                              OPT39650
C=====================================================================OPT39660
C  SUBROUTINE MATPRT -- DISPLAYS A TWO-DIMENSIONAL ARRAY (16 COLS. MAX)=OPT39670
C  IN VARIABLE SCREEN FORMAT FOR USER EASE IN ROW IDENTIFICATION.      =OPT39680
C=====================================================================OPT39690
      SUBROUTINE MATPRT (PRTT,NROW,NCOL)                               OPT39700
      IMPLICIT REAL*8 (A-H,O-Z)                                        OPT39710
      DIMENSION PRTT(NROW,NCOL)                                        OPT39720
C---------------------------------------------------------------------OPT39730
      IF (NCOL.EQ.0)  NCOL=1                                           OPT39740
      IF (NCOL.EQ.1)  WRITE (5,10)  ((PRTT(I,J),J=1,NCOL),I=1,NROW)    OPT39750
      IF (NCOL.EQ.2)  WRITE (5,20)  ((PRTT(I,J),J=1,NCOL),I=1,NROW)    OPT39760
      IF (NCOL.EQ.3)  WRITE (5,30)  ((PRTT(I,J),J=1,NCOL),I=1,NROW)    OPT39770
      IF (NCOL.EQ.4)  WRITE (5,40)  ((PRTT(I,J),J=1,NCOL),I=1,NROW)    OPT39780
      IF (NCOL.EQ.5)  WRITE (5,50)  ((PRTT(I,J),J=1,NCOL),I=1,NROW)    OPT39790
      IF (NCOL.EQ.6)  WRITE (5,60)  ((PRTT(I,J),J=1,NCOL),I=1,NROW)    OPT39800
      IF (NCOL.EQ.7)  WRITE (5,70)  ((PRTT(I,J),J=1,NCOL),I=1,NROW)    OPT39810
      IF (NCOL.EQ.8)  WRITE (5,80)  ((PRTT(I,J),J=1,NCOL),I=1,NROW)    OPT39820
      IF (NCOL.EQ.9)  WRITE (5,90)  ((PRTT(I,J),J=1,NCOL),I=1,NROW)    OPT39830
      IF (NCOL.EQ.10) WRITE (5,100) ((PRTT(I,J),J=1,NCOL),I=1,NROW)    OPT39840
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      IF (NCOL.EQ.11) WRITE (5,110) ((PRTT(I,J),J=1,NCOL),I=1,NROW)      OPT39850
      IF (NCOL.EQ.12) WRITE (5,120) ((PRTT(I,J),J=1,NCOL),I=1,NROW)      OPT39860
      IF (NCOL.EQ.13) WRITE (5,130) ((PRTT(I,J),J=1,NCOL),I=1,NROW)      OPT39870
      IF (NCOL.EQ.14) WRITE (5,140) ((PRTT(I,J),J=1,NCOL),I=1,NROW)      OPT39880
      IF (NCOL.EQ.15) WRITE (5,150) ((PRTT(I,J),J=1,NCOL),I=1,NROW)      OPT39890
      IF (NCOL.EQ.16) WRITE (5,160) ((PRTT(I,J),J=1,NCOL),I=1,NROW)      OPT39900
      RETURN                                                             OPT39910
C-----------------------------------------------------------------------OPT39920
10    FORMAT (F12.5)                                                     OPT39930
20    FORMAT (2F12.5)                                                    OPT39940
30    FORMAT (3F12.5)                                                    OPT39950
40    FORMAT (4F12.5)                                                    OPT39960
50    FORMAT (5F12.5)                                                    OPT39970
60    FORMAT (6F12.5)                                                    OPT39980
70    FORMAT (6F12.5,/,F12.5,//)                                         OPT39990
80    FORMAT (6F12.5,/,2F12.5,//)                                        OPT40000
90    FORMAT (6F12.5,/,3F12.5,//)                                        OPT40010
100   FORMAT (6F12.5,/,4F12.5,//)                                        OPT40020
110   FORMAT (6F12.5,/,5F12.5,//)                                        OPT40030
120   FORMAT (6F12.5,/,6F12.5,//)                                        OPT40040
130   FORMAT (6F12.5,/,6F12.5,/,F12.5,//)                                OPT40050
140   FORMAT (6F12.5,/,6F12.5,/,2F12.5,//)                               OPT40060
150   FORMAT (6F12.5,/,6F12.5,/,3F12.5,//)                               OPT40070
160   FORMAT (6F12.5,/,6F12.5,/,4F12.5,//)                               OPT40080
      END                                                                OPT40090
C=====================================================================OPT40100
C  SUBROUTINE RDMATF -- READS THE FLAGS AND MATRIX SIZES FROM          =OPT40110
C  THE DATA FILE ON FILEDEF 9.  ASKS IF YOU WANT TO USE THE MATRICES.  =OPT40120
C=====================================================================OPT40130
      SUBROUTINE RDMATF (NS,NC,NOB,NG,ISAF,ISAG,ISAH,IGAM,ISAA,ISAB,IRDMOPT40140
     1AT)                                                                OPT40150
      DATA IYES/'Y'/,INO/'N'/                                            OPT40160
C     INTEGER NS,NC,NOB,NG,ISAF,ISAG,ISAH,IGAM,IRDMAT,INO,IANS,K         OPT40170
      REWIND 9                                                           OPT40180
      READ (9,240,END=30,ERR=30) K,IANS                                  OPT40190
      IF (IANS.EQ.1) GO TO 10                                            OPT40200
      GO TO 30                                                           OPT40210
10    READ (9,250) NS,NC,NOB,NG                                          OPT40220
      WRITE (5,255)                                                      OPT40230
      CALL FRTCMS ('CLRSCRN ')                                           OPT40240
20    WRITE (5,260)                                                      OPT40250
      CALL RDINT (IANS)                                                  OPT40260
      IF (IANS.GT.3) GO TO 20                                            OPT40270
      IF (IANS.EQ.3) GO TO 30                                            OPT40280
      IRDMAT=1                                                           OPT40290
      IF (IANS.EQ.2) GO TO 40                                            OPT40300
      ISAF=1                                                             OPT40310
      ISAG=1                                                             OPT40320
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      ISAH=1                                                          OPT40330
      IGAM=1                                                          OPT40340
      ISAA=1                                                          OPT40350
      ISAB=1                                                          OPT40360
30    RETURN                                                          OPT40370
C-----------------------------------------------ISAF-----------------OPT40380
40    CALL FRTCMS ('CLRSCRN ')                                        OPT40390
50    WRITE (5,270)                                                   OPT40400
      CALL RDCHAR (IANS)                                              OPT40410
      IF ((IANS.EQ.IYES).OR.(IANS.EQ.INO)) GO TO 70                   OPT40420
60    WRITE (5,330)                                                   OPT40430
      GO TO 50                                                        OPT40440
70    CONTINUE                                                        OPT40450
      IF (IANS.EQ.IYES) ISAF=1                                        OPT40460
      IF (IANS.EQ.INO) ISAF=0                                         OPT40470
C-----------------------------------------------ISAH-----------------OPT40480
      IF (NOB.EQ.0) GO TO 110                                         OPT40490
      CALL FRTCMS ('CLRSCRN ')                                        OPT40500
80    WRITE (5,280)                                                   OPT40510
      CALL RDCHAR (IANS)                                              OPT40520
      IF ((IANS.EQ.IYES).OR.(IANS.EQ.INO)) GO TO 100                  OPT40530
90    WRITE (5,330)                                                   OPT40540
      GO TO 80                                                        OPT40550
100   CONTINUE                                                        OPT40560
      IF (IANS.EQ.IYES) ISAH=1                                        OPT40570
      IF (IANS.EQ.INO) ISAH=0                                         OPT40580
110   CONTINUE                                                        OPT40590
C-----------------------------------------------ISAG-----------------OPT40600
      IF (NC.EQ.0) GO TO 150                                          OPT40610
      CALL FRTCMS ('CLRSCRN ')                                        OPT40620
120   WRITE (5,290)                                                   OPT40630
      CALL RDCHAR (IANS)                                              OPT40640
      IF ((IANS.EQ.IYES).OR.(IANS.EQ.INO)) GO TO 140                  OPT40650
130   WRITE (5,330)                                                   OPT40660
      GO TO 120                                                       OPT40670
140   CONTINUE                                                        OPT40680
      IF (IANS.EQ.IYES) ISAG=1                                        OPT40690
      IF (IANS.EQ.INO) ISAG=0                                         OPT40700
150   CONTINUE                                                        OPT40710
C-----------------------------------------------IGAM-----------------OPT40720
      IF (NG.EQ.0) GO TO 190                                          OPT40730
      CALL FRTCMS ('CLRSCRN ')                                        OPT40740
160   WRITE (5,300)                                                   OPT40750
      CALL RDCHAR (IANS)                                              OPT40760
      IF ((IANS.EQ.IYES).OR.(IANS.EQ.INO)) GO TO 180                  OPT40770
170   WRITE (5,330)                                                   OPT40780
      GO TO 160                                                       OPT40790
180   CONTINUE                                                        OPT40800
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      IF (IANS.EQ.IYES) IGAM=1                                          OPT40810
      IF (IANS.EQ.INO) IGAM=0                                           OPT40820
190   CONTINUE                                                          OPT40830
C-----------------------------------------------ISAA-------------------OPT40840
      CALL FRTCMS ('CLRSCRN ')                                          OPT40850
200   WRITE (5,310)                                                     OPT40860
      CALL RDCHAR (IANS)                                                OPT40870
      IF ((IANS.EQ.IYES).OR.(IANS.EQ.INO)) GO TO 210                    OPT40880
      WRITE (5,330)                                                     OPT40890
      GO TO 200                                                         OPT40900
210   CONTINUE                                                          OPT40910
      IF (IANS.EQ.IYES) ISAA=1                                          OPT40920
      IF (IANS.EQ.INO) ISAA=0                                           OPT40930
C-----------------------------------------------ISAB-------------------OPT40940
      CALL FRTCMS ('CLRSCRN ')                                          OPT40950
220   WRITE (5,320)                                                     OPT40960
      CALL RDCHAR (IANS)                                                OPT40970
      IF ((IANS.EQ.IYES).OR.(IANS.EQ.INO)) GO TO 230                    OPT40980
      WRITE (5,330)                                                     OPT40990
      GO TO 220                                                         OPT41000
230   CONTINUE                                                          OPT41010
      IF (IANS.EQ.IYES) ISAB=1                                          OPT41020
      IF (IANS.EQ.INO) ISAB=0                                           OPT41030
      RETURN                                                            OPT41040
C-----------------------------------------------------------------------OPT41050
240   FORMAT (I1,3X,I1)                                                 OPT41060
250   FORMAT (4I5)                                                      OPT41070
255   FORMAT (////////////////////)                                     OPT41080
260   FORMAT (//,10X,46HTHE "F", "G", "H", "GAM", "A" AND "B" MATRICES, OPT41090
     1/,12X,42H FROM YOUR PREVIOUS CPTSYS RUN WERE SAVED.,//,10X,36HTHE OPT41100
     2FOLLOWING OPTIONS ARE AVAILABLE:,/15X,38H1. USE ALL OF THE SAME MAOPT41110
     3TRICES AGAIN.,/,15X,'2. USE SELECTED MATRICES AGAIN.',/,          OPT41120
     415X,'3. INPUT ALL NEW MATRICES.',//,10X,17HENTER 1, 2, OR 3.      OPT41130
     5,//,10X,'NOTE: EACH SAVED MATRIX WILL BE REDISPLAYED AT'          OPT41140
     6,/,10X,34HTHE PROPER INPUT SEQUENCE INTERVAL                      OPT41150
     7,/,10X,40HAND YOU WILL HAVE THE OPTION OF CHANGING,/,10X,         OPT41160
     827HINDIVIDUAL MATRIX ELEMENTS.)                                   OPT41170
270   FORMAT (///,5X,48HDO YOU WISH TO SAVE THE "F"-MATRIX FROM THE LASTOPT41180
     1,/,5X,  'RUN TO BE USED IN THIS RUN?'          ,//,5X,39HNOTE: THE NOPT41190
     2ATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCE INTOPT41200
     3ERVAL,/,5X,40HAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27HINDOPT41210
     4IVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)           OPT41220
280   FORMAT (///,5X,48HDO YOU WISH TO SAVE THE "H"-MATRIX FROM THE LASTOPT41230
     1,/,5X,  'RUN TO BE USED IN THIS RUN?'          ,//,5X,39HNOTE: THE NOPT41240
     2ATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCE INTOPT41250
     3ERVAL,/,5X,40HAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27HINDOPT41260
     4IVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)           OPT41270
290   FORMAT (///,5X,48HDO YOU WISH TO SAVE THE "G"-MATRIX FROM THE LASTOPT41280
```

```
     1,/,5X,  'RUN TO BE USED IN THIS RUN?'          ,//,5X,39HNOTE: THE MOPT41290
     2ATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCE INTOPT41300
     3ERVAL,/,5X,40HAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27HINDOPT41310
     4IVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)          OPT41320
200   FORMAT (///,5X,52HDO YOU WISH TO SAVE THE "GAMMA"-MATRIX FROM THE OPT41330
     1LAST,/,5X,  'RUN TO BE USED IN THIS RUN?'          ,//,5X,39HNOTE: TOPT41340
     2HE MATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCEOPT41350
     3 INTERVAL,/,5X,40HAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27OPT41360
     4HINDIVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)      OPT41370
210   FORMAT (///,5X,48HDO YOU WISH TO SAVE THE "A"-MATRIX FROM THE LASTOPT41380
     1,/,5X,  'RUN TO BE USED IN THIS RUN?'          ,//,5X,39HNOTE: THE MOPT41390
     2ATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCE INTOPT41400
     3ERVAL,/,5X,40HAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27HINDOPT41410
     4IVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)          OPT41420
220   FORMAT (///,5X,48HDO YOU WISH TO SAVE THE "B"-MATRIX FROM THE LASTOPT41430
     1,/,5X,  'RUN TO BE USED IN THIS RUN?'          ,//,5X,39HNOTE: THE MOPT41440
     2ATRIX WILL BE REDISPLAYED AT,/,5X,34HTHE PROPER INPUT SEQUENCE INTOPT41450
     3ERVAL,/,5X,40HAND YOU WILL HAVE THE OPTION OF CHANGING,/,5X,27HINDOPT41460
     4IVIDUAL MATRIX ELEMENTS.,//,15X,19HTYPE "YES" OR "NO".)          OPT41470
230   FORMAT (1X,51HWARNING: IMPROPER DATA ENTRY   ENTER "YES" OR "NO".)OPT41480
      END                                                              OPT41490
C=====================================================================OPT41500
C  SUBROUTINE RDMAT -- READS THE F, G, H, GAM, A AND B MATRICES FROM   =OPT41510
C  MATRICES FROM THE DATA FILE OPTMAT ON FILEDEF 9.                    =OPT41520
C=====================================================================OPT41530
      SUBROUTINE RDMAT(BA,G,HO,GAM,FBGC,FBGE,AY,B,NS,NC,NO,NG,IRDMAT)  OPT41540
      IMPLICIT REAL*8(A-H,C-Z)                                         OPT41550
      DIMENSION BA(NS,NS),G(NS,NC),HO(NO,NS),GAM(NS,NG),FBGC(NC,NS),   OPT41560
     1AY(NO,NO),B(NC,NC),FBGE(NS,NO)                                   OPT41570
      IF(IRDMAT.EQ.0) RETURN                                           OPT41580
      REWIND 9                                                         OPT41590
      READ (9,20) K,IANS                                               OPT41600
      READ (9,20) NSI,NCI,NOI,NGI                                      OPT41610
      READ(9,10) ((BA(I,J),J=1,NSI),I=1,NSI)                           OPT41620
      READ(9,10) ((G(I,J),J=1,NCI),I=1,NSI)                            OPT41630
      READ(9,10) ((HO(I,J),J=1,NSI),I=1,NOI)                           OPT41640
      READ(9,10) ((GAM(I,J),J=1,NGI),I=1,NSI)                          OPT41650
      READ(9,10) ((FBGC(I,J),J=1,NSI),I=1,NCI)                         OPT41660
      READ(9,10) ((FBGE(I,J),J=1,NOI),I=1,NSI)                         OPT41670
      READ(9,10) ((AY(I,J),J=1,NOI),I=1,NOI)                           OPT41680
      READ(9,10) ((B(I,J),J=1,NCI),I=1,NCI)                            OPT41690
      RETURN                                                           OPT41700
C--------------------------------------------------------------------- OPT41710
10    FORMAT(4(D20.13))                                                OPT41720
20    FORMAT(4I5)                                                      OPT41730
      END                                                              OPT41740
C=====================================================================OPT41750
C  SUBROUTINE WRTMAT -- WRITES THE F, G, HO & GAM MATRICES TO          =OPT41760
```

```
C  THE DATA FILE OPTMAT ON FILEDEF 9.                                          =OPT41770
C=============================================================================OPT41780
      SUBROUTINE WRTMAT(BA,G,HO,GAM,FBGC,FBGE,AY,B,NS,NC,NO,NG)               OPT41790
      IMPLICIT REAL*8(A-H,O-Z)                                                OPT41800
      DIMENSION BA(NS,NS),G(NS,NC),HO(NO,NS),GAM(NS,NG),FBGC(NC,NS),          OPT41810
     1AY(NO,NO),B(NC,NC),FBGE(NS,NO)                                          OPT41820
C     INTEGER NS,NC,NO,NG,I,J,IANS,INO,IYES                                   OPT41830
      DATA IYES/'Y'/,INO/'N'/                                                 OPT41840
      WRITE (5,90)                                                            OPT41850
      CALL FRTCMS('CLRSCRN ')                                                 OPT41860
10    WRITE(5,100)                                                            OPT41870
      CALL RDCHAR(IANS)                                                       OPT41880
      IF((IANS.EQ.INO).OR.(IANS.EQ.IYES)) GO TO 20                            OPT41890
      WRITE(5,110)                                                            OPT41900
      GO TO 10                                                                OPT41910
20    IF (IANS.EQ.INO) RETURN                                                 OPT41920
      REWIND 9                                                                OPT41930
      I = 0                                                                   OPT41940
      IANS = 1                                                                OPT41950
      WRITE(9,140) I,IANS                                                     OPT41960
      WRITE(9,120) NS,NC,NC,NG                                                OPT41970
      WRITE(9,130) ((BA(I,J),J=1,NS),I=1,NS)                                  OPT41980
      WRITE(9,130) ((G(I,J),J=1,NC),I=1,NS)                                   OPT41990
      WRITE(9,130) ((HO(I,J),J=1,NS),I=1,NO)                                  OPT42000
      WRITE(9,130) ((GAM(I,J),J=1,NG),I=1,NS)                                 OPT42010
      WRITE(9,130) ((FBGC(I,J),J=1,NS),I=1,NC)                                OPT42020
      WRITE(9,130) ((FBGE(I,J),J=1,NO),I=1,NS)                                OPT42030
      WRITE(9,130) ((AY(I,J),J=1,NO),I=1,NO)                                  OPT42040
      WRITE(9,130) ((B(I,J),J=1,NC),I=1,NC)                                   OPT42050
      STOP                                                                    OPT42060
C-----------------------------------------------------------------------------OPT42070
90    FORMAT(////////////////////)                                            OPT42080
100   FORMAT(///,10X,'DO YOU WISH TO OBTAIN A TIME RESPONSE,',/,              OPT42090
     112X,'POLE-ZERO MAP, ROOT-LOCUS PLOT,  BODE PLOT,  NYQUIST',/,           OPT42100
     212X,'PLOT,  OR NICHOLS PLOT OF THE SYSTEM YOU ARE EVALUATING?',         OPT42110
     3/,24X,'(Y OR N)'                                                        OPT42120
     4///,5X,'NOTE: YOU MUST BE LOGGED ON AT A DUAL SCREEN',/,                OPT42130
     410X,'(TEK 618) TERMINAL TO UTILIZE THIS MODE.',///,10X,                 OPT42140
     558HTHE F (SYSTEM), G (CONTROL), H (OBSERVABLES), GAM (NOISE),,/,        OPT42150
     613X,53HA (OUTPUT COST) AND B (CONTROL COST) MATRICES WILL BE,/,         OPT42160
     716X,'SAVED FOR REENTRY TO THE MAIN OPTSYS PROGRAM.')                    OPT42170
110   FORMAT(10X,29HYOU MUST ANSWER (Y)ES OR (N)O  )                          OPT42180
120   FORMAT(4I5)                                                             OPT42190
130   FORMAT(4D20.13)                                                         OPT42200
140   FORMAT(I1,3X,I1)                                                        OPT42210
      END                                                                     OPT42220
```

APPENDIX C
OPTGRAPH PROGRAM LISTING

This portion of the thesis contains the OPTGRAPH FORTRAN program (54 pages).

```
C*************************************************************************OPT00010
C*************************************************************************OPT00020
C**********                                                     **********OPT00030
C**********                      OPTGRAPH                       **********OPT00040
C*********                  BY MICHAEL H.LAPTAS                  *********OPT00050
C*********                                                       *********OPT00060
C*********    THIS PROGRAM IS AN INTERACTIVE DISSPLA GRAPHICS    *********OPT00070
C*********    ROUNTINE USED TO PLOT POLE-ZERO, ROOT-LOCLS, BODE, *********OPT00080
C*********    NYQUIST, AND NICHOLS PLOTS FROM THE OPTSYS PROGRAM *********OPT00090
C*********    OPEN LOOP TRANSFER FUNCTIONS.                       *******OPT00100
C*********                                                       *********OPT00110
C**********                      15 AUG 1984                    **********OPT00120
C**********                                                     **********OPT00130
C*************************************************************************OPT00140
C*************************************************************************OPT00150
      IMPLICIT REAL*8(A-H,C-Z)                                            OPT00160
      REAL*8 MA,MAG                                                       OPT00170
      REAL*4 XDO,YDO,XNO,YNO,GOL                                          OPT00180
      COMPLEX*16 RTN,PLN,RTD,PLD,WN                                       OPT00190
      INTEGER I,J,LL,KK,NC,NS,NOB,IPZ,IRTLO,IBOD,II,JJ,LINES,LINE,K1,K2 OPT00200
     *,NN,IE,IA,IP                                                        OPT00210
      COMMON /GRAFF/ OLN(99,2,12,12),OLD(99,2),GAN(2,12,12),CO            OPT00220
      COMMON /SGRAF/ XDO(500),YDO(500),XNO(500),YNO(500)                  OPT00230
      COMMON /SHEAD/ LINES(4,18),LINE(9)                                  OPT00240
      COMMON /FFREQ/ RTN(99),PLN(99),RTD(99),PLD(99),WN(500),QI(500),     OPT00250
     *GR(500),QPSR(500),MAG(500)                                          OPT00260
      COMMON /SCALE/ TS,TH,TH1,T1,T2,T3,T4,T5,T6,T7,T8,T9,T10             OPT00270
C-------------------------------------------------------------------------OPT00280
C  SUPPRESS POSSIBLE UNDERFLOW AND OVERFLOW ERROR MESSAGES-SUMMARY ONLY=OPT00290
C-------------------------------------------------------------------------OPT00300
      CALL ERRSET (207,256,-1,1,1,209)                                    OPT00310
C--------------------ZERO VARIBLES------------------------------------- OPT00320
      NS = 0                                                              OPT00330
      NC = 0                                                              OPT00340
      NOB = 0                                                             OPT00350
      DO 5 I = 1,2                                                        OPT00360
      DO 5 J = 1,99                                                       OPT00370
5     OLD(J,I) = 0.0                                                      OPT00380
      DO 10 I = 1,12                                                      OPT00390
      DO 10 J = 1,12                                                      OPT00400
      DO 10 KK = 1,2                                                      OPT00410
      DO 10 LL = 1,99                                                     OPT00420
10    OLN(LL,KK,J,I) = 0.0                                                OPT00430
      DO 20 I = 1,12                                                      OPT00440
      DO 20 J = 1,12                                                      OPT00450
      DO 20 KK = 1,2                                                      OPT00460
20    GAN(KK,J,I) = 0.0                                                   OPT00470
C--------------------SELECT TRANSFER FUNCTION TYPE----------------------OPT00480
```

```
30    CALL FRTCMS('CLRSCRN ')                                          OPT00490
      WRITE(6,900)                                                     OPT00500
      WRITE(6,750)                                                     OPT00510
35    WRITE(6,760)                                                     OPT00520
      CALL RDINT(IANS)                                                 OPT00530
      IF(IANS.GT.4.OR.IANS.LT.1) GO TO 34                              OPT00540
      GO TO 36                                                         OPT00550
34    WRITE(6,509)                                                     OPT00560
      GO TO 35                                                         OPT00570
36    CONTINUE                                                         OPT00580
      IF(IANS.EQ.1) IFL = 10                                           OPT00590
      IF(IANS.EQ.2) IFL = 1                                            OPT00600
      IF(IANS.EQ.3) IFL = 4                                            OPT00610
      IF(IANS.EQ.4) GO TO 95                                           OPT00620
C-------------------READ INPUT DISK-------------------------------------OPT00630
      READ(IFL,100) IA,IB,NS,NC,NOB,IE,ITFX                            OPT00640
C-------------------CHECK DATA FILE FOR PROPER DATA---------------------OPT00650
      IF(IB.NE.0) GO TO 41                                             OPT00660
      IF(ITFX.EQ.1) WRITE(6,510)                                       OPT00670
      IF(ITFX.EQ.2) WRITE(6,511)                                       OPT00680
      IF(ITFX.EQ.3) WRITE(6,512)                                       OPT00690
      GO TO 35                                                         OPT00700
41    IF(NS.NE.0) GO TO 42                                             OPT00710
      WRITE(6,513)                                                     OPT00720
      GO TO 35                                                         OPT00730
42    IF(NC.NE.0) GO TO 43                                             OPT00740
      IF(ITFX.EQ.1) WRITE(6,515)                                       OPT00750
      IF(ITFX.EQ.2) WRITE(6,517)                                       OPT00760
      IF(ITFX.EQ.3) WRITE(6,516)                                       OPT00770
      GO TO 35                                                         OPT00780
43    IF(NOB.NE.0) GO TO 44                                            OPT00790
      IF(ITFX.EQ.1) WRITE(6,516)                                       OPT00800
      IF(ITFX.EQ.2) WRITE(6,516)                                       OPT00810
      IF(ITFX.EQ.3) WRITE(6,515)                                       OPT00820
      GO TO 35                                                         OPT00830
C-------------------MARKOV CRITERIA FOR DETERMINING EXTRANEOUS ZEROS----OPT00840
44    IF(IE.EQ.0) IE = 6                                               OPT00850
      CC = 10.**(-IE)                                                  OPT00860
C-------------------DENOMINATOR-----------------------------------------OPT00870
      DO 50 I = 1,NS                                                   OPT00880
         READ(IFL,120) OLD(I,1),OLD(I,2)                               OPT00890
50    CONTINUE                                                         OPT00900
C-------------------NUMERATOR / GAIN / ORDER----------------------------OPT00910
      NN = NOB*NC                                                      OPT00920
      DO 90 I = 1,NN                                                   OPT00930
      READ(IFL,101) KK,K2,K1                                           OPT00940
      READ(IFL,120) GAN(1,K2,K1),GAN(2,K2,K1)                          OPT00950
      IF(GAN(1,K2,K1).NE.0.0) GO TO 72                                 OPT00960
```

```
      DO 70 LL = 1,NS                                                    OPT00970
      CLN(LL,1,K2,K1) = 0.0                                              OPT00980
      CLN(LL,2,K2,K1) = 0.0                                              OPT00990
70    CONTINUE                                                           OPT01000
      GO TO 75                                                           OPT01010
72    CONTINUE                                                           OPT01020
      READ(IFL,120) K2,K1                                                OPT01030
      DO 75 LL = 1,NS                                                    OPT01040
         READ(IFL,120) OLN(LL,1,K2,K1),OLN(LL,2,K2,K1)                   OPT01050
75    CONTINUE                                                           OPT01060
90    CONTINUE                                                           OPT01070
      CALL GRAPH(NS,NC,NOB,IE,ITFX)                                      OPT01080
      GO TO 30                                                           OPT01090
95    CALL DONEPL                                                        OPT01100
      STOP                                                               OPT01110
C-----------------------------------------------------------------------OPT01120
100   FORMAT(I1,I4,5I5)                                                  OPT01130
101   FORMAT(5X,3I5)                                                     OPT01140
120   FORMAT(5X,2D30.14)                                                 OPT01150
130   FORMAT(5X,2I5)                                                     OPT01160
509   FORMAT(/,5X,'****** ERROR ******',10X,'IMPROPER DATA ENTRY',/)     OPT01170
510   FORMAT(/,5X,'****** ERROR ******',/,10X,                           OPT01180
     *'PROPER DATA FILE IS NOT AVAILABLE FOR OPEN LOOP TF ANALYSIS')     OPT01190
511   FORMAT(/,5X,'****** ERROR ******',/,10X,                           OPT01200
     *'PROPER DATA FILE IS NOT AVAILABLE FOR NOISE TF ANALYSIS')         OPT01210
512   FORMAT(/,5X,'****** ERROR ******',/,10X,                           OPT01220
     *'PROPER DATA FILE IS NOT AVAILABLE FOR COMPENSATOR TF ANALYSIS')   OPT01230
513   FORMAT(/,5X,'****** ERROR ******',/,10X,                           OPT01240
     *'MUST INPUT "F" MATRIX IN OPTSYSX PROGRAM')                        OPT01250
515   FORMAT(/,5X,'****** ERROR ******',/,10X,                           OPT01260
     *'MUST INPUT "G" MATRIX IN OPTSYSX PROGRAM')                        OPT01270
516   FORMAT(/,5X,'****** ERROR ******',/,10X,                           OPT01280
     *'MUST INPUT "H" MATRIX IN OPTSYSX PROGRAM')                        OPT01290
517   FORMAT(/,5X,'****** ERROR ******',/,10X,                           OPT01300
     *'MUST INPUT "GAMMA" MATRIX IN OPTSYSX PROGRAM')                    OPT01310
750   FORMAT(/,5X,'DO YOU DESIRE TO ANALYZE:',/,                         OPT01320
     *10X,'1.  OPEN LOOP TRANSFER FUNCTION',/,                          OPT01330
     *10X,'2.  NOISE TRANSFER FUNCTION',/,                              OPT01340
     *10X,'3.  COMPENSATOR TRANSFER FUNCTION',/,                        OPT01350
     *10X,'4.  EXIT OPTGRAPH')                                          OPT01360
760   FORMAT(5X,'ENTER OPTION NUMBER.')                                  OPT01370
900   FORMAT( //,20X,'OPTGRAPH',//)                                      OPT01380
C-----------------------------------------------------------------------OPT01390
      END                                                                OPT01400
C=======================================================================OPT01410
C=======================================================================OPT01420
      SUBROUTINE GRAPH (NS,NC,NOB,IE,ITFX)                               OPT01430
C     CALLS GRAPHICS ROUTINES FOR POLE-ZERO PLOTS, ROOT LOCUS, AND       OPT01440
```

```
C     BODE PLOTS.                                                        OPT01450
C=========================================================================OPT01460
      IMPLICIT REAL*8(A-H,C-Z)                                           OPT01470
      INTEGER II,JJ,LL,KK,NC,NS,NOB,IANS,ITFX                            OPT01480
C-------------------------------------------------------------------------OPT01490
      CALL FRTCMS ('CLRSCRN ')                                           OPT01500
      WRITE(6,900)                                                       OPT01510
      IF(ITFX.EQ.1) WRITE(6,901)                                         OPT01520
      IF(ITFX.EQ.2) WRITE(6,902)                                         OPT01530
      IF(ITFX.EQ.3) WRITE(6,903)                                         OPT01540
      WRITE(6,904) NS,NC,NOB,IE                                          OPT01550
5     CONTINUE                                                           OPT01560
C----------------------INPUT # AND OUTPUT #-------------------------------OPT01570
90    CALL FRTCMS ('CLRSCRN ')                                           OPT01580
      WRITE(6,900)                                                       OPT01590
      WRITE (6,600)                                                      OPT01600
10    WRITE (6,620)                                                      OPT01610
      CALL RDINT (IANS)                                                  OPT01620
      II= IANS                                                           OPT01630
      IF(II.LT.1 .OR.II.GT.NC ) GO TO 15                                 OPT01640
      GO TO 20                                                           OPT01650
15    WRITE(6,510) NC                                                    OPT01660
      GO TO 10                                                           OPT01670
20    WRITE (6,610)                                                      OPT01680
      CALL RDINT (IANS)                                                  OPT01690
      JJ= IANS                                                           OPT01700
      IF(JJ.LT.1 .OR.JJ.GT.NOB) GO TO 25                                 OPT01710
      GO TO 100                                                          OPT01720
25    WRITE(6,520) NOB                                                   OPT01730
      GO TO 20                                                           OPT01740
C----------------------OPTION SCREEN--------------------------------------OPT01750
100   CALL FRTCMS('CLRSCRN ')                                            OPT01760
      WRITE(6,900)                                                       OPT01770
      IF(ITFX.EQ.1) WRITE(6,710)                                         OPT01780
      IF(ITFX.EQ.2) WRITE(6,711)                                         OPT01790
      IF(ITFX.EQ.3) WRITE(6,712)                                         OPT01800
      WRITE(6,720)II                                                     OPT01810
      WRITE(6,730)JJ                                                     OPT01820
      WRITE(6,750)                                                       OPT01830
101   WRITE(6,760)                                                       OPT01840
      CALL RDINT(IANS)                                                   OPT01850
      IF(IANS.GT.7.OR.IANS.LT.1) GO TO 102                               OPT01860
      GO TO 293                                                          OPT01870
102   WRITE(6,509)                                                       OPT01880
      GO TO 101                                                          OPT01890
293   CONTINUE                                                           OPT01900
      ICHG = 1                                                           OPT01910
      GO TO (110,120,130,140,150,90,160),IANS                            OPT01920
```

```
C----------------------POLE-ZERO-------------------------------------OPT01930
110   CALL PZERO(NS,JJ,II,ITFX)                                       OPT01940
      GO TO 100                                                       OPT01950
C----------------------ROOT LOCUS------------------------------------OPT01960
120   CALL RTLO(NS,JJ,II,ITFX)                                        OPT01970
      GO TO 100                                                       OPT01980
C----------------------BODE------------------------------------------OPT01990
130   CALL BODE(NS,JJ,II,ITFX)                                        OPT02000
      GO TO 100                                                       OPT02010
C----------------------NYQUIST---------------------------------------OPT02020
140   CALL NYQST(NS,JJ,II,ITFX)                                       OPT02030
      GO TO 100                                                       OPT02040
C----------------------NICHOLS---------------------------------------OPT02050
150   CALL NICHOL(NS,JJ,II,ITFX)                                      OPT02060
      GO TO 100                                                       OPT02070
C----------------------EXIT OPGRAPH----------------------------------OPT02080
160   CONTINUE                                                        OPT02090
      RETURN                                                          OPT02100
C-----------------------------------------------------------------------OPT02110
500   FORMAT(/,5X,'****** WARNING ******',/,5X,'IMPROPER DATA ENTRY   ', OPT02120
     *3X,'ENTER "YES" OR "NO".',/)                                    OPT02130
509   FORMAT(/,5X,'****** ERROR ******',10X,'IMPROPER DATA ENTRY',/)  OPT02140
510   FORMAT (1X,'WARNING: THE TRANSFER FUNCTION INPUT# MUST NOT BE LESSOPT02150
     * THAN 1 NOR GREATER THAN',I3,'  ')                              OPT02160
520   FORMAT (1X,'WARNING: THE TRANSFER FUNCTION OUTPUT# MUST NOT BE LESOPT02170
     *S THAN 1 NOR GREATER THAN',I3,'  ')                             OPT02180
600   FORMAT (//,5X,'AN OPEN LOOP POLE-ZERO, ROOT LOCUS, BODE, NYQUIST, OPT02190
     *AND/OR NICHOLS',/,5X,'PLOT IS DESIRED FOR:',//)                 OPT02200
610   FORMAT (10X,'OUTPUT # ?')                                       OPT02210
620   FORMAT (10X,'INPUT # ?')                                        OPT02220
710   FORMAT (5X,'OPEN LOOP TRANSFER FUNCTION',/)                     OPT02230
711   FORMAT (5X,'NOISE TRANSFER FUNCTION',/)                         OPT02240
712   FORMAT (5X,'COMPENSATOR TRANSFER FUNCTION',/)                   OPT02250
720   FORMAT (10X,'INPUT #  =',I3)                                    OPT02260
730   FORMAT (10X,'OUTPUT # =',I3)                                    OPT02270
750   FORMAT(/,5X,'DO YOU DESIRE GRAPHICAL RESPONSE AND/OR TABULAR DATA OPT02280
     * FOR:',/,                                                       OPT02290
     *10X,'1.  POLE-ZERO MAP',/,                                      OPT02300
     *10X,'2.  ROOT-LOCUS',/,                                         OPT02310
     *10X,'3.  BODE',/,                                               OPT02320
     *10X,'4.  NYQUIST (POLAR PLOT)',/,                               OPT02330
     *10X,'5.  NICHOLS',/,                                            OPT02340
     *10X,'6.  ANOTHER INPUT/OUTPUT COMBINATION (SAME TRANSFER FUNCTION)OPT02350
     *',/,                                                            OPT02360
     *10X,'7.  ANOTHER TYPE TRANSFER FUNCTION /EXIT OPTGRAPH')        OPT02370
760   FORMAT(5X,'ENTER OPTION NUMBER.')                               OPT02380
900   FORMAT( //,20X,'OPTGRAPH',//)                                   OPT02390
901   FORMAT(5X,'THE OPEN LOOP TRANSFER SYSTEM OBTAINED FROM OPTSYS CONTOPT02400
```

```
     *AINS:',/)                                                                 OPT02410
902   FORMAT(5X,'THE NOISE TRANSFER SYSTEM OBTAINED FROM OPTSYS CONTAINSOPT02420
     *:',/)                                                                     OPT02430
903   FORMAT(5X,'THE COMPENSATOR TRANSFER SYSTEM OBTAINED FROM OPTSYS COOPT02440
     *NTAINS:',/)                                                               OPT02450
904   FORMAT(10X,'1.  NUMBER OF STATES =                ',I3,/,                 OPT02460
     *10X,'2.  NUMBER OF CONTROLS (INPUTS) =      ',I3,/,                       OPT02470
     *10X,'3.  NUMBER OF MEASUREMENTS (OUTPUTS) =',I3,/,                        OPT02480
     *10X,'4.  MARKOV PARAMETER = 10.0**-',I2,//,                               OPT02490
     *15X,'CLEAR SCREEN TO CONTINUE',//////////)                                OPT02500
C-------------------------------------------------------------------------OPT02510
      END                                                                       OPT02520
C=========================================================================OPT02530
C=========================================================================OPT02540
      SUBROUTINE PZERO (NS,K2,K1,ITFX)                                          OPT02550
C     INTERACTIVELY PLOTS A POLE-ZERO PLOT USING DISSPLA GRAPHICS GIVEN OPT02560
C     THE ZERO AND POLE LOCATIONS                                               OPT02570
C=========================================================================OPT02580
      REAL*8 OLN,OLD,ORNUM,GAN,CO,ZERO                                          OPT02590
      REAL*4 XDO,YDO,XNO,YNO,XMIN,XMAX,YMIN,YMAX,XAXIS,YAXIS,PAGEX,             OPT02600
     *PAGEY,XX,YY,GOL,XL,YL,TS,TH,TH1,T1,T2,T3,T4,T5,T6,T7,T8,T9,T10           OPT02610
      INTEGER NS,IPTR,K1,K2,NN,NL,LINES,IANS,ICHG,LINE,J1,ORD,LL,               OPT02620
     *IPT,IPP,IZR,ITFX                                                          OPT02630
      COMMON /GRAFF/ OLN(99,2,12,12),OLD(99,2),GAN(2,12,12),CO                  OPT02640
      COMMON /SGRAF/ XDO(500),YDO(500),XNO(500),YNO(500)                        OPT02650
      COMMON /SHEAD/ LINES(4,18),LINE(9)                                        OPT02660
      COMMON /SCALE/ TS,TH,TH1,T1,T2,T3,T4,T5,T6,T7,T8,T9,T10                   OPT02670
      DATA IY/'Y'/,IZ/'N'/                                                      OPT02680
C----------------------GRAPHIC OR TABULAR OUTPUT----------------------OPT02690
200   CALL FRTCMS('CLRSCRN ')                                                   OPT02700
      WRITE(6,120)                                                              OPT02710
      IF(ITFX.EQ.1) WRITE(6,710)                                                OPT02720
      IF(ITFX.EQ.2) WRITE(6,711)                                                OPT02730
      IF(ITFX.EQ.3) WRITE(6,712)                                                OPT02740
      CALL PRTPLT(IPP)                                                          OPT02750
      GO TO (201,202,80),IPP                                                    OPT02760
C----------------------INPUT ARRAYS----------------------------------OPT02770
201   J1 = 0                                                                    OPT02780
      DO 5 LL =1,NS                                                             OPT02790
      XNO(LL) = 0.0                                                             OPT02800
      YNO(LL) = 0.0                                                             OPT02810
      XDO(LL) = SNGL(OLD(LL,1))                                                 OPT02820
      YDO(LL) = SNGL(OLD(LL,2))                                                 OPT02830
      IF((DABS(OLN(LL,1,K2,K1)).LE.CO).AND.(DABS(OLN(LL,2,K2,K1)).LE.CO)OPT02840
     *) GO TO 6                                                                 OPT02850
      J1= J1+1                                                                  OPT02860
      XNO(J1) = SNGL(OLN(LL,1,K2,K1))                                           OPT02870
      YNO(J1) = SNGL(OLN(LL,2,K2,K1))                                           OPT02880
```

```
6       CONTINUE                                                        OPT02890
5       CONTINUE                                                        OPT02900
        ORD = DINT(GAN(1,K2,K1))                                        OPT02910
        IF(ORD.GT.J1) J1 = ORD                                          OPT02920
        GOL  = SNGL(GAN(2,K2,K1))                                       OPT02930
C-------------------------------------PLOT SETUP----------------------OPT02940
        ICHG = 0                                                        OPT02950
40      CALL FRTCMS('CLRSCRN ')                                         OPT02960
        IF(ICHG.EQ.1) GO TO 41                                          OPT02970
        WRITE (6,120)                                                   OPT02980
        IF(ITFX.EQ.1) WRITE(6,710)                                      OPT02990
        IF(ITFX.EQ.2) WRITE(6,711)                                      OPT03000
        IF(ITFX.EQ.3) WRITE(6,712)                                      OPT03010
41      CALL GSETUP(IPTR,PAGEX,PAGEY)                                   OPT03020
        IF(ICHG.EQ.1) GO TO 90                                          OPT03030
50      CALL FRTCMS('CLRSCRN ')                                         OPT03040
        CALL GGRAF(XMIN,XMAX,YMIN,YMAX)                                 OPT03050
        IF(ICHG.EQ.1) GO TO 90                                          OPT03060
60      CALL FRTCMS('CLRSCRN ')                                         OPT03070
        CALL GHEAD(NL)                                                  OPT03080
        IF(ICHG.EQ.1) GO TO 90                                          OPT03090
70      CONTINUE                                                        OPT03100
        IF(IPTR.EQ.2) GO TO 10                                          OPT03110
C-------------------------------------TEK 618-------------------------OPT03120
        CALL TEK618                                                     OPT03130
        CALL PAGE(PAGEX,PAGEY)                                          OPT03140
        CALL HWROT('AUTO')                                              OPT03150
        CALL HWSCAL('SCREEN')                                           OPT03160
        CALL NOBRDR                                                     OPT03170
        GO TO 20                                                        OPT03180
C-------------------------------------COMPRS--------------------------OPT03190
10      CONTINUE                                                        OPT03200
        CALL COMPRS                                                     OPT03210
        CALL PAGE(PAGEX,PAGEY)                                          OPT03220
20      CONTINUE                                                        OPT03230
C-------------------------------------SCALING CONSTANTS---------------OPT03240
        CALL PSCALE(PAGEX)                                              OPT03250
C-------------------------------------PLOT EXECUTION------------------OPT03260
        CALL NOCHEK                                                     OPT03270
        CALL GRACE(0.)                                                  OPT03280
        CALL PHYSOR(T1,T1)                                              OPT03290
        XAXIS = PAGEX -2.*T1                                            OPT03300
        YAXIS = PAGEY -T1 -T2                                           OPT03310
        CALL AREA2D(XAXIS, YAXIS)                                       OPT03320
        CALL TRIPLX                                                     OPT03330
        CALL HEIGHT(TH)                                                 OPT03340
        CALL XNAME(' $',100)                                            OPT03350
        CALL HEIGHT(TH)                                                 OPT03360
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      CALL YNAME(' $',100)                                                  OPT03370
      CALL GRAF(XMIN,'SCALE',XMAX,YMIN,'SCALE',YMAX)                        OPT03380
      XL = (XMAX-XMIN)*0.1                                                  OPT03390
      YL = (YMAX-YMIN)*0.1                                                  OPT03400
      CALL RLVEC(XMAX+XL,0.0,XMIN-XL,0.0,0000)                              OPT03410
      CALL RLVEC(0.0,YMAX+YL,0.0,YMIN-YL,0000)                              OPT03420
C-----------------------------------------HEADING-----------------------OPT03430
      NN = NL + 1                                                           OPT03440
      IF(NL.EQ.0) GO TO 35                                                  OPT03450
      DO 35 I=1,NL                                                          OPT03460
         CALL CLINE(I)                                                      OPT03470
         CALL HEADIN(LINE,100,T3,NN)                                        OPT03480
35    CONTINUE                                                              OPT03490
      IF(ITFX.EQ.1)                                                         OPT03500
     *   CALL HEADIN('OPEN LOOP TRANSFER POLE-ZERO MAP$',100,T3,NN)         OPT03510
      IF(ITFX.EQ.2)                                                         OPT03520
     *   CALL HEADIN('NOISE TRANSFER POLE-ZERO MAP$',100,T3,NN)             OPT03530
      IF(ITFX.EQ.3)                                                         OPT03540
     *   CALL HEADIN('COMPENSATOR TRANSFER POLE-ZERO MAP$',100,T3,NN)       OPT03550
C-----------------------------------------POLE--------------------------OPT03560
      CALL MARKER(4)                                                        OPT03570
      CALL SCLPIC(2.)                                                       OPT03580
      CALL CURVE(XDO,YDO,NS,-1)                                             OPT03590
C-----------------------------------------ZERO--------------------------OPT03600
      IF(J1.EQ.0) GO TO 36                                                  OPT03610
      CALL MARKER(16)                                                       OPT03620
      CALL SCLPIC(2.)                                                       OPT03630
      CALL CURVE(XNO,YNO,J1,-1)                                             OPT03640
36    CONTINUE                                                              OPT03650
C-----------------------------------------LEGEND------------------------OPT03660
      XX = XAXIS - T7                                                       OPT03670
      YY = YAXIS + T8                                                       OPT03680
      CALL HEIGHT(TH1)                                                      OPT03690
      CALL MESSAG('INPUT # =     $',100,XX+T8,YY+T10)                       OPT03700
      CALL HEIGHT(TH1)                                                      OPT03710
      CALL INTNO(K1,'ABUT','ABUT')                                          OPT03720
      CALL HEIGHT(TH1)                                                      OPT03730
      CALL MESSAG('OUTPUT # =    $',100,XX+T8,YY+T9)                        OPT03740
      CALL HEIGHT(TH1)                                                      OPT03750
      CALL INTNO(K2,'ABUT','ABUT')                                          OPT03760
      CALL HEIGHT(TH1)                                                      OPT03770
      CALL MESSAG('DC GAIN =$',100,XX+T8,YY+T8)                             OPT03780
      CALL HEIGHT(TH1)                                                      OPT03790
      CALL REALNO(GOL,-3,'ABUT','ABUT')                                     OPT03800
      CALL BLREC(XX,YY,T5,T6,0.02)                                          OPT03810
C-----------------------------------------------------------------------OPT03820
C-----------------------------------------GRID--------------------------OPT03830
      CALL DOT                                                              OPT03840
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      CALL GRID(1,1)                                                    OPT03850
      CALL RESET('DOT')                                                 OPT03860
      CALL ENDPL(0)                                                     OPT03870
      IF(IPTR.NE.2) GO TO 90                                            OPT03880
      CALL FRTCMS('CLRSCRN ')                                           OPT03890
      WRITE(6,130)                                                      OPT03900
C-----------------------------------------CHANGES TO PLOT--------------OPT03910
90    CONTINUE                                                          OPT03920
      CALL FRTCMS('CLRSCRN ')                                           OPT03930
      WRITE(6,120)                                                      OPT03940
      IF(ITFX.EQ.1) WRITE(6,710)                                        OPT03950
      IF(ITFX.EQ.2) WRITE(6,711)                                        OPT03960
      IF(ITFX.EQ.3) WRITE(6,712)                                        OPT03970
      WRITE(6,100)                                                      OPT03980
30    WRITE(6,110)                                                      OPT03990
      CALL RDINT(IANS)                                                  OPT04000
      IF(IANS.GT.5.OR.IANS.LT.1) GO TO 15                               OPT04010
      GO TO 25                                                          OPT04020
15    WRITE(6,510)                                                      OPT04030
      GO TO 30                                                          OPT04040
25    CONTINUE                                                          OPT04050
      ICHG = 1                                                          OPT04060
      GO TO (40,50,60,70,200),IANS                                      OPT04070
C-----------------------------------------TABULAR DATA----------------OPT04080
202   CONTINUE                                                          OPT04090
      J1 = 0                                                            OPT04100
      ORD = DINT(GAN(1,K2,K1))                                          OPT04110
      ZERO =0.0                                                         OPT04120
      CALL FRTCMS('CLRSCRN ')                                           OPT04130
      WRITE(6,120)                                                      OPT04140
      IF(ITFX.EQ.1) WRITE(6,710)                                        OPT04150
      IF(ITFX.EQ.2) WRITE(6,711)                                        OPT04160
      IF(ITFX.EQ.3) WRITE(6,712)                                        OPT04170
      CALL PRTR(IPT)                                                    OPT04180
      CALL FRTCMS('CLRSCRN ')                                           OPT04190
      WRITE(IPT,120)                                                    OPT04200
      IF(ITFX.EQ.1) WRITE(IPT,710)                                      OPT04210
      IF(ITFX.EQ.2) WRITE(IPT,711)                                      OPT04220
      IF(ITFX.EQ.3) WRITE(IPT,712)                                      OPT04230
      WRITE(IPT,300) K1                                                 OPT04240
      WRITE(IPT,301) K2                                                 OPT04250
      WRITE(IPT,320) GAN(2,K2,K1)                                       OPT04260
      WRITE(IPT,311) NS                                                 OPT04270
      WRITE(IPT,360)                                                    OPT04280
      WRITE(IPT,340)                                                    OPT04290
      DO 210 I = 1,NS                                                   OPT04300
210   WRITE(IPT,330) OLD(I,1),OLD(I,2)                                  OPT04310
      IF(ORD.EQ.0) GO TO 230                                            OPT04320
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      WRITE(IPT,310) ORD                                                    OPT04330
      WRITE(IPT,350)                                                        OPT04340
      WRITE(IPT,340)                                                        OPT04350
      DO 220 I = 1,NS                                                       OPT04360
      IF((DABS(OLN(I,1,K2,K1)).LE.CO).AND.(DABS(OLN(I,2,K2,K1)).LE.CO)      OPT04370
     *) GO TO 220                                                           OPT04380
      J1= J1+1                                                              OPT04390
      WRITE(IPT,330) CLN(I,1,K2,K1),OLN(I,2,K2,K1)                          OPT04400
220   CONTINUE                                                              OPT04410
      IZR = ORD - J1                                                        OPT04420
      IF(IZR.LE.0) GO TO 240                                                OPT04430
      DO 225 I = 1,IZR                                                      OPT04440
225   WRITE(IPT,330) ZERO, ZERO                                             OPT04450
      GO TO 240                                                             OPT04460
230   WRITE(IPT,350)                                                        OPT04470
      WRITE(IPT,360)                                                        OPT04480
C-----------------------------------------CHANGES FOR TABULAP DATA-----OPT04490
240   IF(IPT.EQ.3) WRITE (6,401)                                            OPT04500
      IF(IPT.EQ.2) WRITE (6,402)                                            OPT04510
      WRITE(6,400)                                                          OPT04520
      CALL RDCHAR (IANS)                                                    OPT04530
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 245                          OPT04540
      GO TO 250                                                             OPT04550
245   WRITE (6,500)                                                         OPT04560
      GO TO 240                                                             OPT04570
250   CONTINUE                                                              OPT04580
      IF (IANS.EQ.IY) GO TO 202                                             OPT04590
      IF (IANS.EQ.IZ) GO TO 200                                             OPT04600
C-------------------------------------------------------------------OPT04610
80    RETURN                                                                OPT04620
C-------------------------------------------------------------------OPT04630
100   FORMAT(//,5X,'DO YOU DESIRE TO MAKE ANY CHANGES TO:',//,10X,'1.  POPT04640
     *LOTTER / PAGE SIZE',/,10X,'2.  GRAPH LIMITS',/,10X,'3.  HEADING',/OPT04650
     *,10X,'4.  NO ADDITIONAL CHANGES - PLOT POLE-ZERO MAP',/,10X,'5.  NOPT04660
     *O CHANGES - EXIT POLE-ZERO PLOTTING ROUTINE',/)                      OPT04670
110   FORMAT(/,5X,'ENTER OPTION NUMBER.',/)                                 OPT04680
120   FORMAT(//,15X,'POLE-ZERO MAP')                                        OPT04690
130   FORMAT(/////////,15X,'A DISSPLA METAFILE HAS BEEN CREATED',/,         OPT04700
     *15X,'CLEAR SCREEN TO CONTINUE',//////////////////////)                OPT04710
300   FORMAT(//,10X,'INPUT NUMBER =  ',I5)                                  OPT04720
301   FORMAT(10X,'OUTPUT NUMBER =  ',I5)                                    OPT04730
310   FORMAT(/,10X,'NUMERATOR ORDER =',I5)                                  OPT04740
311   FORMAT(/,10X,'DENOMINATOR ORDER =',I5)                                OPT04750
320   FORMAT(10X,'TRANSFER FUNCTION (DC) GAIN =',D12.4,/)                   OPT04760
330   FORMAT(10X,D12.4,5X,D12.4)                                            OPT04770
340   FORMAT(12X,'REAL PART',8X,'IMAGINARY PART',/)                         OPT04780
350   FORMAT(5X,'ZERO LOCATIONS')                                           OPT04790
360   FORMAT(5X,'POLE LOCATIONS')                                           OPT04800
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300   FORMAT(/,15X,'NO REAL ZEROS',/)                                   OPT04810
400   FORMAT (/,5X,'DO YOU DESIRE TO CHANGE OUTPUT DEVICE?'             OPT04820
     *,/,10X,'TYPE "YES" OR "NO".',/)                                   OPT04830
401   FORMAT(////,5X,'OUTPUT SENT TO PRINTER',/)                        OPT04840
402   FORMAT(////,5X,'OUTPUT SENT TO LISTING FILE',/)                   OPT04850
500   FORMAT(/,5X,'****** WARNING *****',/,5X,'IMPROPER DATA ENTRY   ', OPT04860
     *3X,'ENTER "YES" OR "NO".',/)                                      OPT04870
510   FORMAT(/,5X,'****** ERROR ******',10X,'IMPROPER DATA ENTRY',/)    OPT04880
710   FORMAT (5X,'OPEN LOOP TRANSFER FUNCTION',/)                       OPT04890
711   FORMAT (5X,'NOISE TRANSFER FUNCTION',/)                           OPT04900
712   FORMAT (5X,'COMPENSATOR TRANSFER FUNCTION',/)                     OPT04910
C-----------------------------------------------------------------------OPT04920
      END                                                               OPT04930
C=======================================================================OPT04940
C=======================================================================OPT04950
      SUBROUTINE RTLO (NS,K2,K1,ITFX)                                   OPT04960
C     INTERACTIVELY PLOTS A ROOT-LOCUS PLOT USING DISSPLA GRAPHICS GIVENOPT04970
C     THE ZERO AND POLE LOCATIONS                                       OPT04980
C=======================================================================OPT04990
      REAL*8 OLD,CLN,MAG,QI,QR,QPSR,KMAX,KMIN,ZERO,GAIN,                OPT05000
     *DELTF,GAN,CC,XR,YI,CRNUM,K,KIC                                    OPT05010
      REAL*4 XDO,YDO,XNO,YNO,XMIN,XMAX,YMIN,YMAX,XAXIS,YAXIS,PAGEX,     OPT05020
     *PAGEY,XX,YY,GOL,XL,YL,TS,TH,T1,T2,T3,T4,T5,T6,T7,T8,TH1,T9,T10    OPT05030
      COMPLEX*16 RTN,PLN,RTD,PLD,CPOLN,WN,CPOLD,CPOL                    OPT05040
      INTEGER NS,IPTR,II,JJ,NN,NL,LINES,IANS,ICHG,LINE,J1,ORD,ITFX,     OPT05050
     *I,L,N,N1,N2,K2,K1,NN1,NN2,ND1,ND2,J,LL,IER,PTS,IPT,IZR            OPT05060
      COMMON /GRAFF/ OLN(99,2,12,12),OLD(99,2),GAN(2,12,12),CO          OPT05070
      COMMON /SGRAF/ XDO(500),YDO(500),XNO(500),YNO(500)                OPT05080
      COMMON /SHEAD/ LINES(4,18),LINE(9)                                OPT05090
      COMMON /FFREQ/ RTN(99),PLN(99),RTD(99),PLD(99),WN(500),QI(500),   OPT05100
     *QR(500),QPSR(500),MAG(500)                                        OPT05110
      COMMON /SCALE/ TS,TH,TH1,T1,T2,T3,T4,T5,T6,T7,T8,T9,T10           OPT05120
      DATA IY/'Y'/,IZ/'N'/                                              OPT05130
C----------------------GRAPHIC OR TABULAR OUTPUT------------------------OPT05140
200   CALL FRTCMS('CLRSCRN ')                                           OPT05150
      WRITE(6,120)                                                      OPT05160
      IF(ITFX.EQ.1) WRITE(6,710)                                        OPT05170
      IF(ITFX.EQ.2) WRITE(6,711)                                        OPT05180
      IF(ITFX.EQ.3) WRITE(6,712)                                        OPT05190
      CALL PRTPLT(IPP)                                                  OPT05200
      GO TO (201,202,80),IPP                                            OPT05210
C-----------------------------------------PLOT SETUP--------------------OPT05220
201   CONTINUE                                                          OPT05230
      ICHG = 0                                                          OPT05240
40    CALL FRTCMS('CLRSCRN ')                                           OPT05250
      IF(ICHG.EQ.1) GO TO 41                                            OPT05260
      WRITE (6,120)                                                     OPT05270
      IF(ITFX.EQ.1) WRITE(6,710)                                        OPT05280
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      IF(ITEX.EQ.2) WRITE(6,711)                                        OPT05290
      IF(ITEX.EQ.3) WRITE(6,712)                                        OPT05300
41    CALL GSETUP(IPTR,PAGEX,PAGEY)                                     OPT05310
      IF(ICHG.EQ.1) GO TO 90                                            OPT05320
50    CALL FRTCMS('CLRSCRN ')                                           OPT05330
      CALL GGRAF(XMIN,XMAX,YMIN,YMAX)                                   OPT05340
      IF(ICHG.EQ.1) GO TO 90                                            OPT05350
55    CALL FRTCMS('CLRSCRN ')                                           OPT05360
      CALL RANGK(KMIN,KMAX)                                             OPT05370
      IF(ICHG.EQ.1) GO TO 90                                            OPT05380
60    CALL FRTCMS('CLRSCRN ')                                           OPT05390
      CALL GHEAD(NL)                                                    OPT05400
      IF(ICHG.EQ.1) GO TO 90                                            OPT05410
70    CONTINUE                                                          OPT05420
      IF(IPTR.EQ.2) GO TO 10                                            OPT05430
C-----------------------------------------TEK 618-----------------------OPT05440
      CALL TEK618                                                       OPT05450
      CALL PAGE(PAGEX,PAGEY)                                            OPT05460
      CALL HWROT('AUTO')                                                OPT05470
      CALL HWSCAL('SCREEN')                                             OPT05480
      CALL NOBRDR                                                       OPT05490
      GO TO 20                                                          OPT05500
C-----------------------------------------COMPRS------------------------OPT05510
10    CONTINUE                                                          OPT05520
      CALL COMPRS                                                       OPT05530
      CALL PAGE(PAGEX,PAGEY)                                            OPT05540
20    CONTINUE                                                          OPT05550
C-----------------------------------------SCALING CONSTANTS-------------OPT05560
      CALL PSCALE(PAGEX)                                                OPT05570
C-----------------------------------------PLOT EXECUTION----------------OPT05580
      CALL NOCHEK                                                       OPT05590
      CALL GRACE(0.)                                                    OPT05600
      CALL PHYSOR(T1,T1)                                                OPT05610
         XAXIS = PAGEX -2.0*T1                                          OPT05620
         YAXIS = PAGEY -T1 -T2                                          OPT05630
      CALL AREA2D(XAXIS, YAXIS)                                         OPT05640
      CALL TRIPLX                                                       OPT05650
      CALL HEIGHT(TH)                                                   OPT05660
      CALL XNAME(' $',100)                                              OPT05670
      CALL HEIGHT(TH)                                                   OPT05680
      CALL YNAME(' $',100)                                              OPT05690
      CALL GRAF(XMIN,'SCALE',XMAX,YMIN,'SCALE',YMAX)                    OPT05700
      XL = (XMAX-XMIN)*0.1                                              OPT05710
      YL = (YMAX-YMIN)*0.1                                              OPT05720
      CALL RLVEC(XMAX+XL,0.0,XMIN-XL,0.0,0000)                          OPT05730
      CALL RLVEC(0.0,YMAX+YL,0.0,YMIN-YL,0000)                          OPT05740
C-----------------------------------------HEADING-----------------------OPT05750
      NN = NL + 1                                                       OPT05760
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      IF(NL.EQ.0) GO TO 35                                                  OPT05770
      DO 35 I=1,NL                                                          OPT05780
         CALL CLINE(I)                                                      OPT05790
         CALL HEADIN(LINE,100,T3,NN)                                        OPT05800
35    CONTINUE                                                              OPT05810
      IF(ITFX.EQ.1)                                                         OPT05820
     *   CALL HEADIN('ROOT-LOCUS PLOT (OPEN LOOP TF)$',100,T3,NN)           OPT05830
      IF(ITFX.EQ.2)                                                         OPT05840
     *   CALL HEADIN('ROOT-LOCUS PLOT (NOISE TF)$',100,T3,NN)               OPT05850
      IF(ITFX.EQ.3)                                                         OPT05860
     *   CALL HEADIN('ROOT-LOCUS PLOT (COMPENSATOR TF)$',100,T3,NN)         OPT05870
C---------------------INPUT ARRAYS-------------------------------------     OPT05880
      ZERO = 0.0                                                            OPT05890
      J1 = 0                                                                OPT05900
      ND1 = NS + 1                                                          OPT05910
      ND2 = NS + 2                                                          OPT05920
      DO 5 LL =1,NS                                                         OPT05930
      XNO(LL) = 0.0                                                         OPT05940
      YNO(LL) = 0.0                                                         OPT05950
      QI(LL) = 0.0                                                          OPT05960
      QR(LL) = 0.0                                                          OPT05970
      XDO(LL) = SNGL(OLD(LL,1))                                             OPT05980
      YDO(LL) = SNGL(OLD(LL,2))                                             OPT05990
      RTD(LL) = DCMPLX(OLD(LL,1),OLD(LL,2))                                 OPT06000
      RTN(LL) = DCMPLX(ZERO,ZERO)                                           OPT06010
      IF((DABS(OLN(LL,1,K2,K1)).LE.CO).AND.(DABS(OLN(LL,2,K2,K1)).LE.CO)OPT06020
     *) GO TO 6                                                             OPT06030
      J1= J1+1                                                              OPT06040
      XNO(J1) = SNGL(OLN(LL,1,K2,K1))                                       OPT06050
      YNO(J1) = SNGL(OLN(LL,2,K2,K1))                                       OPT06060
      RTN(J1) = DCMPLX(OLN(LL,1,K2,K1),OLN(LL,2,K2,K1))                     OPT06070
6     CONTINUE                                                              OPT06080
5     CONTINUE                                                              OPT06090
      ORD = DINT(GAN(1,K2,K1))                                              OPT06100
      IF(ORD.GT.J1) J1 = ORD                                                OPT06110
      GOL  = SNGL(GAN(2,K2,K1))                                             OPT06120
      GAIN = GAN(2,K2,K1)                                                   OPT06130
C---------------------------------------POLE-----------------------------OPT06140
      CALL MARKER(4)                                                        OPT06150
      CALL SCLPIC(2.)                                                       OPT06160
      CALL CURVE(XDO,YDO,NS,-1)                                             OPT06170
C---------------------------------------ZERO-----------------------------OPT06180
      IF(J1.EQ.0) GO TO 36                                                  OPT06190
      CALL MARKER(16)                                                       OPT06200
      CALL SCLPIC(2.)                                                       OPT06210
      CALL CURVE(XNO,YNO,J1,-1)                                             OPT06220
36    CONTINUE                                                              OPT06230
C---------------------------------------POLYNOMIALS----------------------OPT06240
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C-----------------------------------------DENOMENATOR-----------------OPT06250
      CALL MAKPOL(NS,RTD,PLD)                                          OPT06260
      QI(1) = 1.0                                                      OPT06270
      DO 7 I = 2,ND1                                                   OPT06280
7     QI(I) = DREAL(PLD(ND2-I))                                        OPT06290
C-----------------------------------------NUMERATOR-------------------OPT06300
      IF(J1.EQ.0) GO TO 9                                              OPT06310
      CALL MAKPOL(J1,RTN,PLN)                                          OPT06320
      JJ = NS - J1 + 2                                                 OPT06330
      QR(JJ-1) = 1.0                                                   OPT06340
      DO 8 I = JJ,ND1                                                  OPT06350
8     QR(I) = DREAL(PLN(ND2-I))                                        OPT06360
      GO TO 11                                                         OPT06370
9     QR(ND1) = 1.0                                                    OPT06380
      QR(1) = 0.0                                                      OPT06390
C-----------------------------------------ROOT FINDING ROUTINE---------OPT06400
11    KIC = (KMAX-KMIN)/2000.                                          OPT06410
      K = KMIN                                                         OPT06420
      DO 52 J = 1,2000                                                 OPT06430
      DO 37 II = 1,ND1                                                 OPT06440
      MAG(II) = QI(II) + K*GAIN*QR(II)                                 OPT06450
37    CONTINUE                                                         OPT06460
      CALL ZRPOLY(MAG,NS,WN,IER)                                       OPT06470
      DO 51 II =1,NS                                                   OPT06480
      XR = DREAL(WN(II))                                               OPT06490
      XNO(II) = SNGL(XR)                                               OPT06500
      YI = DIMAG(WN(II))                                               OPT06510
      YNO(II) = SNGL(YI)                                               OPT06520
51    CONTINUE                                                         OPT06530
      CALL MARKER(4)                                                   OPT06540
      CALL SCLPIC(1.)                                                  OPT06550
      CALL CURVE(XNO,YNO,NS,-1)                                        OPT06560
      K=K+KIC                                                          OPT06570
52    CONTINUE                                                         OPT06580
C-----------------------------------------LEGEND----------------------OPT06590
      XX = XAXIS - T7                                                  OPT06600
      YY = YAXIS + T8                                                  OPT06610
      CALL HEIGHT(TH1)                                                 OPT06620
      CALL MESSAG('INPUT # =    $',100,XX+T8,YY+T10)                   OPT06630
      CALL HEIGHT(TH1)                                                 OPT06640
      CALL INTNO(K1,'ABUT','ABUT')                                     OPT06650
      CALL HEIGHT(TH1)                                                 OPT06660
      CALL MESSAG('OUTPUT # =   $',100,XX+T8,YY+T9)                    OPT06670
      CALL HEIGHT(TH1)                                                 OPT06680
      CALL INTNO(K2,'ABUT','ABUT')                                     OPT06690
      CALL HEIGHT(TH1)                                                 OPT06700
      CALL MESSAG('DC GAIN =$',100,XX+T8,YY+T8)                        OPT06710
      CALL HEIGHT(TH1)                                                 OPT06720
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      CALL REALNC(GOL,-3,'ABUT','ABUT')                                 OPT06730
      CALL BLREC(XX,YY,T5,T6,0.02)                                      OPT06740
C-----------------------------------------GRID-------------------------OPT06750
      CALL DOT                                                          OPT06760
      CALL GRID(1,1)                                                    OPT06770
      CALL RESET('DOT')                                                 OPT06780
      CALL ENDPL(0)                                                     OPT06790
      IF(IPTR.NE.2) GO TO 90                                            OPT06800
      CALL FRTCMS('CLRSCRN ')                                           OPT06810
      WRITE(6,130)                                                      OPT06820
C---------------------------------------CHANGES TO PLOT-----------------OPT06830
90    CONTINUE                                                          OPT06840
      CALL FRTCMS('CLRSCRN ')                                           OPT06850
      WRITE(6,120)                                                      OPT06860
      IF(ITFX.EQ.1) WRITE(6,710)                                        OPT06870
      IF(ITFX.EQ.2) WRITE(6,711)                                        OPT06880
      IF(ITFX.EQ.3) WRITE(6,712)                                        OPT06890
      WRITE(6,100)                                                      OPT06900
30    WRITE(6,110)                                                      OPT06910
      CALL RDINT(IANS)                                                  OPT06920
      IF(IANS.GT.6.OR.IANS.LT.1) GO TO 15                               OPT06930
      GO TO 25                                                          OPT06940
15    WRITE(6,510)                                                      OPT06950
      GO TO 30                                                          OPT06960
25    CONTINUE                                                          OPT06970
      ICHG = 1                                                          OPT06980
      GO TO (40,50,60,55,70,200),IANS                                   OPT06990
C---------------------------------------TABULAR DATA--------------------OPT07000
202   CONTINUE                                                          OPT07010
      ICHG =0                                                           OPT07020
251   CALL FRTCMS('CLRSCRN ')                                           OPT07030
      IF(ICHG.EQ.1) GO TO 249                                           OPT07040
      WRITE(6,120)                                                      OPT07050
      IF(ITFX.EQ.1) WRITE(6,710)                                        OPT07060
      IF(ITFX.EQ.2) WRITE(6,711)                                        OPT07070
      IF(ITFX.EQ.3) WRITE(6,712)                                        OPT07080
249   CALL PRTR(IPT)                                                    OPT07090
      IF(ICHG.EQ.1) GO TO 290                                           OPT07100
252   CALL FRTCMS('CLRSCRN ')                                           OPT07110
      CALL RANGK(KMIN,KMAX)                                             OPT07120
      IF(ICHG.EQ.1) GO TO 290                                           OPT07130
253   CALL FRTCMS('CLRSCRN ')                                           OPT07140
      CALL NPTS(PTS)                                                    OPT07150
      IF(ICHG.EQ.1) GO TO 290                                           OPT07160
C---------------------------------------TABULATE DATA-------------------OPT07170
254   CONTINUE                                                          OPT07180
      ZERO = 0.0                                                        OPT07190
      J1 = 0                                                            OPT07200
```

```
      ND1 = NS + 1                                                          OPT07210
      ND2 = NS + 2                                                          OPT07220
      ORD = DINT(GAN(1,K2,K1))                                              OPT07230
      GAIN = GAN(2,K2,K1)                                                   OPT07240
      CALL FRTCMS('CLRSCRN ')                                               OPT07250
      WRITE(IPT,120)                                                        OPT07260
      IF(ITFX.EQ.1) WRITE(IPT,710)                                          OPT07270
      IF(ITFX.EQ.2) WRITE(IPT,711)                                          OPT07280
      IF(ITFX.EQ.3) WRITE(IPT,712)                                          OPT07290
      WRITE(IPT,300) K1                                                     OPT07300
      WRITE(IPT,301) K2                                                     OPT07310
      WRITE(IPT,320) GAN(2,K2,K1)                                           OPT07320
      IF(ITFX.EQ.1) WRITE(IPT,121)                                          OPT07330
      IF(ITFX.EQ.2) WRITE(IPT,122)                                          OPT07340
      IF(ITFX.EQ.3) WRITE(IPT,123)                                          OPT07350
      WRITE(IPT,311) NS                                                     OPT07360
      WRITE(IPT,360)                                                        OPT07370
      WRITE(IPT,240)                                                        OPT07380
      DO 210 I = 1,NS                                                       OPT07390
210   WRITE(IPT,330) OLD(I,1),OLD(I,2)                                      OPT07400
      IF(ORD.EQ.0) GO TO 230                                                OPT07410
      WRITE(IPT,210) ORD                                                    OPT07420
      WRITE(IPT,350)                                                        OPT07430
      WRITE(IPT,240)                                                        OPT07440
      DO 220 I = 1,NS                                                       OPT07450
      RTD(I) = DCMPLX(OLD(I,1),OLD(I,2))                                    OPT07460
      RTN(I) = DCMPLX(ZERO,ZERO)                                            OPT07470
      IF((DABS(OLN(I,1,K2,K1)).LE.CC).AND.(DABS(CLN(I,2,K2,K1)).LE.CC)      OPT07480
     *) GO TO 220                                                           OPT07490
      J1= J1+1                                                              OPT07500
      RTN(J1) = DCMPLX(OLN(I,1,K2,K1),OLN(I,2,K2,K1))                       OPT07510
      WRITE(IPT,330) OLN(I,1,K2,K1),OLN(I,2,K2,K1)                          OPT07520
220   CONTINUE                                                              OPT07530
      IZR = ORD - J1                                                        OPT07540
      IF(IZR.LE.0) GO TO 240                                                OPT07550
      DO 225 I = 1,IZR                                                      OPT07560
225   WRITE(IPT,330) ZERO, ZERO                                             OPT07570
      GO TO 240                                                             OPT07580
230   WRITE(IPT,350)                                                        OPT07590
      WRITE(IPT,380)                                                        OPT07600
C-----------------------------------------POLYNOMIALS-----------------OPT07610
C-----------------------------------------DENOMENATOR-----------------OPT07620
240   CONTINUE                                                              OPT07630
      CALL MAKPOL(NS,RTD,PLD)                                               OPT07640
      QI(1) = 1.0                                                           OPT07650
      DO 207 I = 2,ND1                                                      OPT07660
207   QI(I) = DREAL(PLD(ND2-I))                                             OPT07670
C-----------------------------------------NUMERATOR-------------------OPT07680
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```
      IF(J1.EQ.0) GO TO 209                                              OPT07690
      CALL MAKPOL(J1,RTN,PLN)                                            OPT07700
      JJ = NS - J1 + 2                                                   OPT07710
      QR(JJ-1) = 1.0                                                     OPT07720
      DO 208 I = JJ,ND1                                                  OPT07730
208   QR(I) = CREAL(PLN(ND2-I))                                          OPT07740
      GO TO 211                                                          OPT07750
209   QR(ND1) = 1.0                                                      OPT07760
      QR(1) = 0.0                                                        OPT07770
C-----------------------------------------ROOT FINDING ROUTINE---------OPT07780
      WRITE(IPT,220)                                                     OPT07790
211   KIC = (KMAX-KMIN)/DFLOAT(PTS)                                      OPT07800
      K = KMIN                                                           OPT07810
      DO 262 J = 1,PTS                                                   OPT07820
      DO 237 II = 1,ND1                                                  OPT07830
      MAG(II) = CI(II) + K*GAIN*QR(II)                                   OPT07840
237   CONTINUE                                                           OPT07850
      CALL ZRPOLY(MAG,NS,WN,IER)                                         OPT07860
      WRITE(IPT,221) K                                                   OPT07870
      WRITE(IPT,240)                                                     OPT07880
      DO 261 II =1,NS                                                    OPT07890
      XR = DREAL(WN(II))                                                 OPT07900
      YI = DIMAG(WN(II))                                                 OPT07910
      WRITE(IPT,230) XR,YI                                               OPT07920
261   CONTINUE                                                           OPT07930
      K=K+KIC                                                            OPT07940
262   CONTINUE                                                           OPT07950
C-----------------------------------------CHANGES TABULAR DATA---------OPT07960
241   IF(IPT.EQ.2) WRITE (6,401)                                         OPT07970
      IF(IPT.EQ.2) WRITE (6,402)                                         OPT07980
      WRITE(6,400)                                                       OPT07990
      CALL RDCHAR (IANS)                                                 OPT08000
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 245                       OPT08010
      GO TO 250                                                          OPT08020
245   WRITE (6,500)                                                      OPT08030
      GO TO 241                                                          OPT08040
250   CONTINUE                                                           OPT08050
      IF (IANS.EQ.IY) GO TO 290                                          OPT08060
      IF (IANS.EQ.IZ) GO TO 200                                          OPT08070
C-----------------------------------------CHANGES ---------------------OPT08080
290   CONTINUE                                                           OPT08090
      CALL FRTCMS('CLRSCRN ')                                            OPT08100
      WRITE(6,120)                                                       OPT08110
      IF(ITFX.EQ.1) WRITE(6,710)                                         OPT08120
      IF(ITFX.EQ.2) WRITE(6,711)                                         OPT08130
      IF(ITFX.EQ.3) WRITE(6,712)                                         OPT08140
      WRITE(6,410)                                                       OPT08150
291   WRITE(6,110)                                                       OPT08160
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      CALL RDINT(IANS)                                                  OPT08170
      IF(IANS.GT.5.OR.IANS.LT.1) GO TO 292                              OPT08180
      GO TO 293                                                         OPT08190
292   WRITE(6,510)                                                      OPT08200
      GO TO 291                                                         OPT08210
293   CONTINUE                                                          OPT08220
      ICHG = 1                                                          OPT08230
      GO TO (251,252,253,254,200),IANS                                  OPT08240
C-----------------------------------------------------------------------OPT08250
80    RETURN                                                            OPT08260
C-----------------------------------------------------------------------OPT08270
100   FORMAT(//,5X,'DO YOU DESIRE TO MAKE ANY CHANGES TO:',//,10X,'1.  POPT08280
     *LOTTER / PAGE SIZE',/,10X,'2.  GRAPH LIMITS',/,10X,               OPT08290
     *'3.  HEADING',/,10X,'4.  GAIN RANGE',/                            OPT08300
     *,10X,'5.  NO ADDITIONAL CHANGES - PLOT ROOT-LOCUS',/,10X,         OPT08310
     *'6.  NO CHANGES - EXIT ROOT-LOCUS PLOTTING ROUTINE',/)            OPT08320
110   FORMAT(/,5X,'ENTER OPTION NUMBER.',/)                             OPT08330
120   FORMAT(//,15X,'ROOT-LOCUS')                                       OPT08340
121   FORMAT(/,5X,'OPEN LOOP TF POLES AND ZEROS')                       OPT08350
122   FORMAT(/,5X,'NOISE TF POLES AND ZEROS')                           OPT08360
123   FORMAT(/,5X,'COMPENSATOR TF POLES AND ZEROS')                     OPT08370
130   FORMAT(/////////,15X,'A DISSPLA METAFILE HAS BEEN CREATED',/,     OPT08380
     *15X,'CLEAR SCREEN TO CONTINUE',////////////////////)              OPT08390
300   FORMAT(//,10X,'INPUT NUMBER =  ',I5)                              OPT08400
301   FORMAT(10X,'OUTPUT NUMBER =  ',I5)                                OPT08410
310   FORMAT(/,10X,'NUMERATOR ORDER =',I5)                              OPT08420
311   FORMAT(/,10X,'DENOMINATOR ORDER =',I5)                            OPT08430
320   FORMAT(10X,'TRANSFER FUNCTION (DC) GAIN =',D12.4,/)               OPT08440
321   FORMAT(/,10X,'GAIN = ',D12.4)                                     OPT08450
330   FORMAT(10X,D12.4,5X,D12.4)                                        OPT08460
340   FORMAT(12X,'REAL PART',8X,'IMAGINARY PART',/)                     OPT08470
350   FORMAT(10X,'ZERO LOCATIONS')                                      OPT08480
360   FORMAT(10X,'POLE LOCATIONS')                                      OPT08490
380   FORMAT(/,15X,'NO REAL ZEROS',/)                                   OPT08500
400   FORMAT (/,5X,'DO YOU DESIRE TO MAKE ANY CHANGES ?',/,             OPT08510
     *10X,'TYPE "YES" OR "NO".',/)                                     OPT08520
401   FORMAT(////,5X,'OUTPUT SENT TO PRINTER',/)                        OPT08530
402   FORMAT(////,5X,'OUTPUT SENT TO LISTING FILE',/)                   OPT08540
410   FORMAT(//,5X,'DO YOU DESIRE TO MAKE ANY CHANGES TO:',//,          OPT08550
     *10X,'1.  OUTPUT DEVICE',/,                                       OPT08560
     *10X,'2.  GAIN RANGE',/,                                          OPT08570
     *10X,'3.  NUMBER OF POINTS CALCULATED',/,                         OPT08580
     *10X,'4.  NO ADDITIONAL CHANGES - TABULATE DATA',/,               OPT08590
     *10X,'5.  EXIT ROOT-LOCUS TABULAR DATA ROUTINE',/)                OPT08600
500   FORMAT(/,5X,'****** WARNING ******',/,5X,'IMPROPER DATA ENTRY   ', OPT08610
     *3X,'ENTER "YES" OR "NO".',/)                                     OPT08620
510   FORMAT(/,5X,'****** ERROR ******',10X,'IMPROPER DATA ENTRY',/)    OPT08630
710   FORMAT (5X,'OPEN LOOP TRANSFER FUNCTION',/)                       OPT08640
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711   FORMAT (5X,'NOISE TRANSFER FUNCTION',/)                          OPT08650
712   FORMAT (5X,'COMPENSATOR TRANSFER FUNCTION',/)                    OPT08660
C-----------------------------------------------------------------------OPT08670
      END                                                              OPT08680
C=======================================================================OPT08690
C=======================================================================OPT08700
      SUBROUTINE BODE (NS,K2,K1,ITFX)                                  OPT08710
C     INTERATIVELY PLOTS A BODE PLOT USING DISSPLA GRAPHICS GIVEN      OPT08720
C     THE ZERO AND POLE LOCATIONS                                      OPT08730
C=======================================================================OPT08740
      REAL*8 OLN,OLD,ORNUM,MA,OMEGA,QI,QR,QPSR,MAG,GAN,CO              OPT08750
      REAL*4 XDO,YDO,XNO,YNO,FMIN,FMAX,MMIN,MMAX,XAXIS,YAXIS,PAGEX,    OPT08760
     *PAGEY,XX,YY,PMIN,PMAX,MCYCLE,PCYCLE,FCYCLE,GOL,FL,FU,PM,GM,      OPT08770
     *TH,TH1,TS,T1,T2,T3,T4,T5,T6,T7,T8,T9,T10                         OPT08780
      COMPLEX*16 RTN,PLN,RTD,PLD,WN                                    OPT08790
      INTEGER NS,IPTR,K1,K2,NN,NL,LINES,IANS,ICHG,LINE,N,IPP,PTS,IPT   OPT08800
     *,ORD,ITFX                                                        OPT08810
      COMMON /GRAFF/ OLN(99,2,12,12),OLD(99,2),GAN(2,12,12),CO         OPT08820
      COMMON /SGRAF/ XDO(500),YDO(500),XNO(500),YNO(500)               OPT08830
      COMMON /SHEAD/ LINES(4,18),LINE(9)                               OPT08840
      COMMON /FFREQ/ RTN(99),PLN(99),RTD(99),PLD(99),WN(500),QI(500),  OPT08850
     *QR(500),QPSR(500),MAG(500)                                       OPT08860
      COMMON /SCALE/ TS,TH,TH1,T1,T2,T3,T4,T5,T6,T7,T8,T9,T10          OPT08870
      DATA IY/'Y'/,IZ/'N'/                                             OPT08880
C----------------------GRAPHIC OR TABULAR OUTPUT-----------------------OPT08890
200   CALL FRTCMS('CLRSCRN ')                                          OPT08900
      WRITE(6,120)                                                     OPT08910
      IF(ITFX.EQ.1) WRITE(6,710)                                       OPT08920
      IF(ITFX.EQ.2) WRITE(6,711)                                       OPT08930
      IF(ITFX.EQ.3) WRITE(6,712)                                       OPT08940
      CALL PRTPLT(IPP)                                                 OPT08950
      GO TO (201,202,80),IPP                                           OPT08960
C-----------------------------------------PLOT SETUP-------------------OPT08970
201   CONTINUE                                                         OPT08980
      N = 500                                                          OPT08990
      ICHG = 0                                                         OPT09000
      IF(GAN(2,K2,K1).EQ.0.0) GO TO 95                                 OPT09010
40    CALL FRTCMS('CLRSCRN ')                                          OPT09020
      IF(ICHG.EQ.1) GO TO 41                                           OPT09030
      WRITE (6,120)                                                    OPT09040
      IF(ITFX.EQ.1) WRITE(6,710)                                       OPT09050
      IF(ITFX.EQ.2) WRITE(6,711)                                       OPT09060
      IF(ITFX.EQ.3) WRITE(6,712)                                       OPT09070
41    CALL GSETUP(IPTR,PAGEX,PAGEY)                                    OPT09080
      IF(ICHG.EQ.1) GO TO 90                                           OPT09090
50    CALL FRTCMS('CLRSCRN ')                                          OPT09100
      CALL FGRAF(FMIN,FMAX)                                            OPT09110
      IF(ICHG.EQ.1) GO TO 90                                           OPT09120
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60    CALL FRTCMS('CLRSCRN ')                                          OPT09130
      CALL GHEAD(NL)                                                   OPT09140
      IF(ICHG.EQ.1) GO TO 90                                           OPT09150
70    CONTINUE                                                         OPT09160
C-----------------------------------------SCALING CONSTANTS-----------OPT09170
      CALL PSCALE(PAGEX)                                               OPT09180
C-----------------------------------------INPUT ARRAYS----------------OPT09190
      GOL  = SNGL(GAN(2,K2,K1))                                        OPT09200
      FL = FMIN*0.1                                                    OPT09210
      FU = FMAX*0.1                                                    OPT09220
      XAXIS = PAGEX -2.*T1                                             OPT09230
      YAXIS = PAGEY -T1 -T2                                            OPT09240
      FCYCLE = XAXIS/(ALOG10(FMAX)-ALOG10(FMIN))                       OPT09250
      CALL FREQ(NS,K2,K1,FMIN,FMAX,N)                                  OPT09260
      DO 5 I =1,N                                                      OPT09270
      OMEGA = DIMAG(WN(I))                                             OPT09280
      XNO(I) = SNGL(OMEGA)                                             OPT09290
      MA = 20.0*DLOG10(MAG(I))                                         OPT09300
      YNO(I) = SNGL(MA)                                                OPT09310
      YDO(I) = SNGL(QPSR(I))                                           OPT09320
5     CONTINUE                                                         OPT09330
      CALL MINMAX(N,YNO,MMIN,MMAX)                                     OPT09340
      MMIN = AINT(MMIN) - 1.0                                          OPT09350
      MCYCLE = (MMAX-MMIN)/YAXIS                                       OPT09360
      MCYCLE = AINT(MCYCLE) + 1.0                                      OPT09370
      CALL MINMAX(N,YDO,PMIN,PMAX)                                     OPT09380
      PMIN = AINT(PMIN) - 1.0                                          OPT09390
      PCYCLE = (PMAX-PMIN)/YAXIS                                       OPT09400
      PCYCLE = AINT(PCYCLE) + 1.0                                      OPT09410
C-----------------------------------------MAGNITUDE PLOT--------------OPT09420
C-----------------------------------------TEK 618---------------------OPT09430
      IF(IPTR.EQ.2) GO TO 10                                           OPT09440
      CALL TEK618                                                      OPT09450
      CALL PAGE(PAGEX,PAGEY)                                           OPT09460
      CALL HWROT('AUTO')                                               OPT09470
      CALL HWSCAL('SCREEN')                                            OPT09480
      CALL NOBRDR                                                      OPT09490
      GO TO 20                                                         OPT09500
C-----------------------------------------COMPRS----------------------OPT09510
10    CONTINUE                                                         OPT09520
      CALL CCMPRS                                                      OPT09530
      CALL PAGE(PAGEX,PAGEY)                                           OPT09540
20    CONTINUE                                                         OPT09550
C-----------------------------------------PLOT EXECUTION--------------OPT09560
      CALL NOCHEK                                                      OPT09570
      CALL GRACE(0.)                                                   OPT09580
      CALL PHYSOR(T1,T1)                                               OPT09590
      CALL AREA2D(XAXIS, YAXIS)                                        OPT09600
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      CALL TRIPLX                                                        OPT09610
      CALL HEIGHT(TH)                                                    OPT09620
      CALL XNAME('FREQUENCY - RADIANS PER SECOND $',100)                 OPT09630
      CALL HEIGHT(TH)                                                    OPT09640
      CALL YNAME('MAGNITUDE - DECIBELS $',100)                           OPT09650
      CALL XLOG(FMIN,FCYCLE,MMIN,MCYCLE)                                 OPT09660
      CALL RLVEC(FMAX+FU,0.0,FMIN-FL,0.0,0000)                           OPT09670
C-----------------------------------------HEADING-----------------------OPT09680
      NN = NL + 1                                                        OPT09690
      IF(NL.EQ.0) GO TO 35                                               OPT09700
      DO 35 I=1,NL                                                       OPT09710
         CALL CLINE(I)                                                   OPT09720
         CALL HEADIN(LINE,100,T3,NN)                                     OPT09730
35    CONTINUE                                                           OPT09740
      IF(ITFX.EQ.1)                                                      OPT09750
     *   CALL HEADIN('OPEN LOOP TF BODE MAGNITUDE$',100,T3,NN)           OPT09760
      IF(ITFX.EQ.2)                                                      OPT09770
     *   CALL HEADIN('NOISE TF BODE MAGNITUDE$',100,T3,NN)               OPT09780
      IF(ITFX.EQ.3)                                                      OPT09790
     *   CALL HEADIN('COMPENSATOR TF BODE MAGNITUDE$',100,T3,NN)         OPT09800
C---------------------------------------MAGNITUDE-----------------------OPT09810
      CALL CURVE(XNO,YNO,N,0)                                            OPT09820
C-----------------------------------------LEGEND------------------------OPT09830
      XX = XAXIS - T7                                                    OPT09840
      YY = YAXIS + T8                                                    OPT09850
      CALL HEIGHT(TH1)                                                   OPT09860
      CALL MESSAG('INPUT # =     $',100,XX+T8,YY+T10)                    OPT09870
      CALL HEIGHT(TH1)                                                   OPT09880
      CALL INTNO(K1,'ABUT','ABUT')                                       OPT09890
      CALL HEIGHT(TH1)                                                   OPT09900
      CALL MESSAG('OUTPUT # =    $',100,XX+T8,YY+T9)                     OPT09910
      CALL HEIGHT(TH1)                                                   OPT09920
      CALL INTNO(K2,'ABUT','ABUT')                                       OPT09930
      CALL HEIGHT(TH1)                                                   OPT09940
      CALL MESSAG('DC GAIN =$',100,XX+T8,YY+T8)                          OPT09950
      CALL HEIGHT(TH1)                                                   OPT09960
      CALL REALNO(GOL,-3,'ABUT','ABUT')                                  OPT09970
      CALL BLREC(XX,YY,T5,T6,0.02)                                       OPT09980
C-------------------------------------------GRID------------------------OPT09990
      CALL DOT                                                           OPT10000
      CALL GRID(1,1)                                                     OPT10010
      CALL RESET('DOT')                                                  OPT10020
      CALL ENDPL(C)                                                      OPT10030
C---------------------------------------PHASE PLOT----------------------OPT10040
C-----------------------------------------TEK 618-----------------------OPT10050
      IF(IPTR.EQ.2) GO TO 11                                             OPT10060
      CALL TEK618                                                        OPT10070
      CALL PAGE(PAGEX,PAGEY)                                             OPT10080
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      CALL HWROT('AUTO')                                                OPT10090
      CALL HWSCAL('SCREEN')                                             OPT10100
      CALL NOBRDR                                                       OPT10110
      GO TO 21                                                          OPT10120
C-----------------------------------------COMPRS----------------------OPT10130
11    CONTINUE                                                          OPT10140
      CALL COMPRS                                                       OPT10150
      CALL PAGE(PAGEX,PAGEY)                                            OPT10160
21    CONTINUE                                                          OPT10170
C-----------------------------------------PLOT EXECUTION---------------OPT10180
      CALL NOCHEK                                                       OPT10190
      CALL GRACE(0.)                                                    OPT10200
      CALL PHYSOR(T1,T1)                                                OPT10210
      CALL AREA2D(XAXIS, YAXIS)                                         OPT10220
      CALL TRIPLX                                                       OPT10230
      CALL HEIGHT(TH)                                                   OPT10240
      CALL XNAME('FREQUENCY - RADIANS PER SECOND $',100)                OPT10250
      CALL HEIGHT(TH)                                                   OPT10260
      CALL YNAME('PHASE - DEGREES $',100)                               OPT10270
      CALL XLOG(FMIN,FCYCLE,PMIN,PCYCLE)                                OPT10280
      CALL RLVEC(FMAX+FU,180.0,FMIN-FL,180.0,0000)                      OPT10290
      CALL RLVEC(FMAX+FU,-180.0,FMIN-FL,-180.0,0000)                    OPT10300
C-----------------------------------------HEADING----------------------OPT10310
      NN = NL + 1                                                       OPT10320
      IF(NL.EQ.0) GO TO 36                                              OPT10330
      DO 36 I=1,NL                                                      OPT10340
         CALL CLINE(I)                                                  OPT10350
         CALL HEADIN(LINE,100,T3,NN)                                    OPT10360
36    CONTINUE                                                          OPT10370
      IF(ITFX.EQ.1)                                                     OPT10380
     *   CALL HEADIN('OPEN LOOP TF BODE PHASE$',100,T3,NN)              OPT10390
      IF(ITFX.EQ.2)                                                     OPT10400
     *   CALL HEADIN('NOISE TF BODE PHASE$',100,T3,NN)                  OPT10410
      IF(ITFX.EQ.3)                                                     OPT10420
     *   CALL HEADIN('COMPENSATOR TF BODE PHASE$',100,T3,NN)            OPT10430
C-----------------------------------------PHASE------------------------OPT10440
      CALL CURVE(XNC,YDO,N,0)                                           OPT10450
C-----------------------------------------LEGEND-----------------------OPT10460
      XX = XAXIS - T7                                                   OPT10470
      YY = YAXIS + T8                                                   OPT10480
      CALL HEIGHT(TH1)                                                  OPT10490
      CALL MESSAG('INPUT # =     $',100,XX+T8,YY+T10)                   OPT10500
      CALL HEIGHT(TH1)                                                  OPT10510
      CALL INTNO(K1,'ABUT','ABUT')                                      OPT10520
      CALL HEIGHT(TH1)                                                  OPT10530
      CALL MESSAG('OUTPUT # =    $',100,XX+T8,YY+T9)                    OPT10540
      CALL HEIGHT(TH1)                                                  OPT10550
      CALL INTNO(K2,'ABUT','ABUT')                                      OPT10560
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      CALL HEIGHT(TH1)                                                  OPT10570
      CALL MESSAG('DC GAIN =$',100,XX+T8,YY+T8)                         OPT10580
      CALL HEIGHT(TH1)                                                  OPT10590
      CALL REALNC(GOL,-3,'ABUT','ABUT')                                 OPT10600
      CALL BLREC(XX,YY,T5,T6,0.02)                                      OPT10610
C-----------------------------------------GRID-------------------------OPT10620
      CALL DOT                                                          OPT10630
      CALL GRID(1,1)                                                    OPT10640
      CALL RESET('DOT')                                                 OPT10650
      CALL ENDPL(0)                                                     OPT10660
      IF(IPTR.NE.2) GO TO 75                                            OPT10670
      CALL FRTCMS('CLRSCRN ')                                           OPT10680
      WRITE(6,130)                                                      OPT10690
C-----------------------------------GAIN AND PHASE MARGIN--------------OPT10700
75    CALL FRTCMS('CLRSCRN ')                                           OPT10710
      WRITE(6,135)                                                      OPT10720
C-----------------------------------------GAIN MARGIN------------------OPT10730
      DO 71 I = 2,N                                                     OPT10740
      IF(ABS(YDO(I-1)).LT.180.0.AND.ABS(YDO(I)).GE.180.0) GO TO 72      OPT10750
      IF(ABS(YDO(I-1)).GT.180.0.AND.ABS(YDO(I)).LE.180.0) GO TO 72      OPT10760
      GO TO 71                                                          OPT10770
72    GM = 0.0 - YNO(I)                                                 OPT10780
      WRITE (6,140) XNO(I), GM                                          OPT10790
71    CONTINUE                                                          OPT10800
C-----------------------------------------PHASE MARGIN-----------------OPT10810
      DO 76 I = 2,N                                                     OPT10820
      IF(YNO(I-1).GT.0.0.AND.YNO(I).LE.0.0) GO TO 77                    OPT10830
      GO TO 76                                                          OPT10840
77    PM = 180.0 + YDO(I)                                               OPT10850
      WRITE (6,150) XNO(I), PM                                          OPT10860
76    CONTINUE                                                          OPT10870
      WRITE(6,160)                                                      OPT10880
C-----------------------------------CHANGES TO PLOT---------------------OPT10890
90    CONTINUE                                                          OPT10900
      CALL FRTCMS('CLRSCRN ')                                           OPT10910
      WRITE(6,120)                                                      OPT10920
      IF(ITFX.EQ.1) WRITE(6,710)                                        OPT10930
      IF(ITFX.EQ.2) WRITE(6,711)                                        OPT10940
      IF(ITFX.EQ.3) WRITE(6,712)                                        OPT10950
      WRITE(6,100)                                                      OPT10960
30    WRITE(6,110)                                                      OPT10970
      CALL RDINT(IANS)                                                  OPT10980
      IF(IANS.GT.5.OR.IANS.LT.1) GO TO 15                               OPT10990
      GO TO 25                                                          OPT11000
15    WRITE(6,510)                                                      OPT11010
      GO TO 30                                                          OPT11020
25    CONTINUE                                                          OPT11030
      ICHG = 1                                                          OPT11040
```

```
      GO TO (40,50,60,70,200),IANS                                      OPT11050
C-----------------------------------------TABULAR DATA-----------------OPT11060
202   CONTINUE                                                          OPT11070
      IF(GAN(2,K2,K1).EQ.0.0) GO TO 95                                  OPT11080
      ICHG =0                                                           OPT11090
251   CALL FRTCMS('CLRSCRN ')                                           OPT11100
      IF(ICHG.EQ.1) GO TO 249                                           OPT11110
      WRITE(6,120)                                                      OPT11120
      IF(ITFX.EQ.1) WRITE(6,710)                                        OPT11130
      IF(ITFX.EQ.2) WRITE(6,711)                                        OPT11140
      IF(ITFX.EQ.3) WRITE(6,712)                                        OPT11150
249   CALL PRTR(IPT)                                                    OPT11160
      IF(ICHG.EQ.1) GO TO 290                                           OPT11170
252   CALL FRTCMS('CLRSCRN ')                                           OPT11180
      CALL FGRAF(FMIN,FMAX)                                             OPT11190
      IF(ICHG.EQ.1) GO TO 290                                           OPT11200
253   CALL FRTCMS('CLRSCRN ')                                           OPT11210
      CALL NPTS(PTS)                                                    OPT11220
      IF(ICHG.EQ.1) GO TO 290                                           OPT11230
C-----------------------------------------TABULATE DATA----------------OPT11240
254   CONTINUE                                                          OPT11250
      ZERO = 0.0                                                        OPT11260
      J1 = 0                                                            OPT11270
      ORD = DINT(GAN(1,K2,K1))                                          OPT11280
      GAIN = GAN(2,K2,K1)                                               OPT11290
      CALL FRTCMS('CLRSCRN ')                                           OPT11300
      WRITE(IPT,120)                                                    OPT11310
      IF(ITFX.EQ.1) WRITE(IPT,710)                                      OPT11320
      IF(ITFX.EQ.2) WRITE(IPT,711)                                      OPT11330
      IF(ITFX.EQ.3) WRITE(IPT,712)                                      OPT11340
      WRITE(IPT,200) K1                                                 OPT11350
      WRITE(IPT,201) K2                                                 OPT11360
      WRITE(IPT,211) NS                                                 OPT11370
      WRITE(IPT,210) ORD                                                OPT11380
      WRITE(IPT,220) GAN(2,K2,K1)                                       OPT11390
      WRITE(IPT,250)                                                    OPT11400
      N = PTS                                                           OPT11410
      CALL FREQ(NS,K2,K1,FMIN,FMAX,N)                                   OPT11420
      DO 220 I = 1,N                                                    OPT11430
      OMEGA = DIMAG(WN(I))                                              OPT11440
      MA = 20.0*DLOG10(MAG(I))                                          OPT11450
      WRITE(IPT,330) OMEGA,MA,QPSR(I),QR(I),QI(I)                       OPT11460
220   CONTINUE                                                          OPT11470
C-----------------------------------------CHANGES TABULAR DATA---------OPT11480
240   IF(IPT.EQ.3) WRITE (6,401)                                        OPT11490
      IF(IPT.EQ.2) WRITE (6,402)                                        OPT11500
      WRITE(6,400)                                                      OPT11510
      CALL RDCHAR (IANS)                                                OPT11520
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      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 245                      OPT11530
      GO TO 250                                                         OPT11540
245   WRITE (6,500)                                                     OPT11550
      GO TO 240                                                         OPT11560
250   CONTINUE                                                          OPT11570
      IF (IANS.EQ.IY) GO TO 290                                         OPT11580
      IF (IANS.EQ.IZ) GO TO 200                                         OPT11590
C-----------------------------------------CHANGES ---------------------OPT11600
290   CONTINUE                                                          OPT11610
      CALL FRTCMS('CLRSCRN ')                                           OPT11620
      WRITE(6,120)                                                      OPT11630
      IF(ITFX.EQ.1) WRITE(6,710)                                        OPT11640
      IF(ITFX.EQ.2) WRITE(6,711)                                        OPT11650
      IF(ITFX.EQ.3) WRITE(6,712)                                        OPT11660
      WRITE(6,410)                                                      OPT11670
291   WRITE(6,110)                                                      OPT11680
      CALL RDINT(IANS)                                                  OPT11690
      IF(IANS.GT.5.OR.IANS.LT.1) GO TO 292                              OPT11700
      GO TO 293                                                         OPT11710
292   WRITE(6,510)                                                      OPT11720
      GO TO 291                                                         OPT11730
293   CONTINUE                                                          OPT11740
      ICHG = 1                                                          OPT11750
      GO TO (251,252,253,254,200),IANS                                  OPT11760
C-----------------------------------------------------------------------OPT11770
80    RETURN                                                            OPT11780
95    WRITE(6,520)                                                      OPT11790
      RETURN                                                            OPT11800
C-----------------------------------------------------------------------OPT11810
100   FORMAT(//,5X,'DO YOU DESIRE TO MAKE ANY CHANGES TO:',//,10X,'1.  POPT11820
     *LOTTER / PAGE SIZE',/,10X,'2.  GRAPH LIMITS (FREQUENCY RANGE)',   OPT11830
     */10X,'3.  HEADING',/                                              OPT11840
     *,10X,'4.  NO ADDITIONAL CHANGES - PLOT BODE PLOTS',/,10X,'5.  NO COPT11850
     *HANGES - EXIT BODE SUBROUTINE',/)                                 OPT11860
110   FORMAT(/,5X,'ENTER OPTION NUMBER.',/)                             OPT11870
120   FORMAT(//,15X,'BODE PLOT')                                        OPT11880
130   FORMAT(/////////,15X,'A DISSPLA METAFILE HAS BEEN CREATED',/,     OPT11890
     *15X,'CLEAR SCREEN TO CONTINUE',////////////////////)              OPT11900
135   FORMAT(////,15X,'GAIN MARGIN AND PHASE MARGIN',/)                 OPT11910
140   FORMAT(/,3X,'PHASE CROSSOVER FREQUENCY IS',F10.4,' RAD/SEC;'1X,   OPT11920
     *'GAIN MARGIN IS ',F10.4,' DB')                                    OPT11930
150   FORMAT(/,3X,'GAIN CROSSOVER FREQUENCY IS ',F10.4,' RAD/SEC;',1X,  OPT11940
     *,'PHASE MARGIN IS',F10.4,' DEG')                                  OPT11950
160   FORMAT(//,15X,'CLEAR SCREEN TO CONTINUE',////////////////////)    OPT11960
300   FORMAT(//,10X,'INPUT NUMBER =     ',I5)                           OPT11970
301   FORMAT(10X,'OUTPUT NUMBER =     ',I5)                             OPT11980
310   FORMAT(10X,'NUMERATOR ORDER =  ',I5)                              OPT11990
311   FORMAT(10X,'DENOMINATOR ORDER =',I5)                              OPT12000
```

```
320   FORMAT(10X,'TRANSFER FUNCTION (DC) GAIN =',D12.4,/)                    OPT12010
330   FORMAT(5X,D12.4,3X,D12.4,3X,D12.4,3X,D12.4,3X,D12.4)                   OPT12020
350   FORMAT(5X,'  FREQUENCY ',3X,'   MAGNITUDE ',3X,' PHASE     ',         OPT12030
     * 3X,'    REAL     ',3X,'   IMAGINARY',                               OPT12040
     */,5X,'  (RAD/SEC)  ',3X,'  (DECIBELS)',3X,' (DEGREES)',               OPT12050
     * 3X,'     PART     ',3X,'    PART     ')                             OPT12060
400   FORMAT (/,5X,'DO YOU DESIRE TO MAKE ANY CHANGES ?',/,                  OPT12070
     *10X,'TYPE "YES" OR "NO".',/)                                          OPT12080
401   FORMAT(////,5X,'OUTPUT SENT TO PRINTER',/)                             OPT12090
402   FORMAT(////,5X,'OUTPUT SENT TO LISTING FILE',/)                        OPT12100
410   FORMAT(//,5X,'DO YOU DESIRE TO MAKE ANY CHANGES TO:',//,               OPT12110
     *10X,'1.  OUTPUT DEVICE',/,                                            OPT12120
     *10X,'2.  FREQUENCY RANGE',/,                                          OPT12130
     *10X,'3.  NUMBER OF POINTS CALCULATED',/,                              OPT12140
     *10X,'4.  NC ADDITIONAL CHANGES - TABULATE DATA',/,                    OPT12150
     *10X,'5.  EXIT BODE TABULAR DATA ROUTINE',/)                           OPT12160
500   FORMAT(/,5X,'****** WARNING ******',/,5X,'IMPROPER DATA ENTRY   ',    OPT12170
     *3X,'ENTER "YES" OR "NO".',/)                                          OPT12180
501   FORMAT(/,5X,'****** WARNING ******',/,5X,'IMPROPER DATA ENTRY   ',    OPT12190
     *3X,'ENTER "YES" TO CONTINUE',/)                                       OPT12200
510   FORMAT(/,5X,'****** ERROR ******',10X,'IMPROPER DATA ENTRY',/)         OPT12210
520   FORMAT(/,5X,'****** WARNING ******',10X,'NUMERATOR IS EQUAL TC ZEROPT12220
     *0',/)                                                                 OPT12230
710   FORMAT (5X,'OPEN LOOP TRANSFER FUNCTION',/)                            OPT12240
711   FORMAT (5X,'NOISE TRANSFER FUNCTION',/)                                OPT12250
712   FORMAT (5X,'COMPENSATOR TRANSFER FUNCTION',/)                          OPT12260
C-----------------------------------------------------------------------OPT12270
      END                                                                   OPT12280
C=======================================================================OPT12290
C=======================================================================OPT12300
      SUBROUTINE NYQST (NS,K2,K1,ITFX)                                      OPT12310
C     INTERATIVELY PLOTS A NYQUIST PLOT USING DISSPLA GRAPHICS GIVEN      OPT12320
C     THE ZERO AND POLE LOCATIONS                                         OPT12330
C=======================================================================OPT12340
      REAL*8 OLN,CLD,ORNUM,CI,QR,QPSR,MAG,GAN,CO,MA,OMEGA                   OPT12350
      REAL*4 XDO,YDO,XNO,YNO,FMIN,FMAX,MMIN,MMAX,XAXIS,YAXIS,PAGEX,         OPT12360
     *PAGEY,XX,YY,GOL,FL,FU,PM,GM,C2,C3,TS,TH,T1,T2,T3,T4,T5,T6,T7,T8,     OPT12370
     *QRMIN,QRMAX,QIMIN,QIMAX,RL,B1,B2,B3,RSTEP,THEFAC,TH1,T9,T10           OPT12380
      COMPLEX*16 RTN,PLN,RTD,PLD,WN                                         OPT12390
      INTEGER NS,IPTR,K1,K2,NN,NL,LINES,IANS,ICHG,LINE,N,CRD,IPP,PTS,IPTOPT12400
     *,KK,J,II,N1,ITFX                                                     OPT12410
      COMMON /GRAFF/ OLN(99,2,12,12),OLD(99,2),GAN(2,12,12),CC              OPT12420
      COMMON /SGRAF/ XDO(500),YDO(500),XNO(500),YNO(500)                    OPT12430
      COMMON /SHEAD/ LINES(4,18),LINE(9)                                    OPT12440
      COMMON /FFREQ/ RTN(99),PLN(99),RTD(99),PLD(99),WN(500),QI(500),       OPT12450
     *QR(500),QPSR(500),MAG(500)                                           OPT12460
      COMMON /SCALE/ TS,TH,TH1,T1,T2,T3,T4,T5,T6,T7,T8,T9,T10               OPT12470
      DATA IY/'Y'/,IZ/'N'/                                                  OPT12480
```

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C----------------------GRAPHIC OR TABULAR OUTPUT----------------------OPT12490
200   CALL FRTCMS('CLRSCRN ')                                          OPT12500
      WRITE(6,120)                                                     OPT12510
      IF(ITFX.EQ.1) WRITE(6,710)                                       OPT12520
      IF(ITFX.EQ.2) WRITE(6,711)                                       OPT12530
      IF(ITFX.EQ.3) WRITE(6,712)                                       OPT12540
      CALL PRTPLT(IPP)                                                 OPT12550
      GO TO (201,202,80),IPP                                           OPT12560
C-----------------------------------------PLOT SETUP------------------OPT12570
201   CONTINUE                                                         OPT12580
      N = 500                                                          OPT12590
      ICHG = 0                                                         OPT12600
      IF(GAN(2,K2,K1).EQ.0.0) GO TO 95                                 OPT12610
40    CALL FRTCMS('CLRSCRN ')                                          OPT12620
      IF(ICHG.EQ.1) GO TO 41                                           OPT12630
      WRITE (6,120)                                                    OPT12640
      IF(ITFX.EQ.1) WRITE(6,710)                                       OPT12650
      IF(ITFX.EQ.2) WRITE(6,711)                                       OPT12660
      IF(ITFX.EQ.3) WRITE(6,712)                                       OPT12670
41    CALL GSETUP(IPTR,PAGEX,PAGEY)                                    OPT12680
      IF(ICHG.EQ.1) GO TO 90                                           OPT12690
50    CALL FRTCMS('CLRSCRN ')                                          OPT12700
      CALL FGRAF(FMIN,FMAX)                                            OPT12710
      IF(ICHG.EQ.1) GO TO 90                                           OPT12720
60    CALL FRTCMS('CLRSCRN ')                                          OPT12730
      CALL GHEAD(NL)                                                   OPT12740
      IF(ICHG.EQ.1) GO TO 90                                           OPT12750
70    CONTINUE                                                         OPT12760
C-----------------------------------------SCALING CONSTANTS------------OPT12770
      CALL PSCALE(PAGEX)                                               OPT12780
C-----------------------------------------INPUT ARRAYS-----------------OPT12790
      COL   = SNGL(GAN(2,K2,K1))                                       OPT12800
      CALL FREQ(NS,K2,K1,FMIN,FMAX,N)                                  OPT12810
      DO 5 I =1,N                                                      OPT12820
      XNO(I) = SNGL(QR(I))                                             OPT12830
      YNO(I) = SNGL(QI(I))                                             OPT12840
5     CONTINUE                                                         OPT12850
      CALL MINMAX(N,XNO,QRMIN,QRMAX)                                   OPT12860
      CALL MINMAX(N,YNO,QIMIN,QIMAX)                                   OPT12870
C-----------------------------------------PLOT LIMITS------------------OPT12880
      XAXIS = PAGEX -2.*T1                                             OPT12890
      YAXIS = PAGEY -T1 -T2                                            OPT12900
      IF(QRMIN.GT.-1.) QRMIN = -1.0                                    OPT12910
      IF(QRMAX.LT.0.0) QRMAX = 0.0                                     OPT12920
      IF(QIMIN.GT.0.0) QIMIN = 0.0                                     OPT12930
      IF(QIMAX.LT.0.0) QIMAX = 0.0                                     OPT12940
      IF((QRMAX-QRMIN).GE.(QIMAX-QIMIN)) GO TO 6                       OPT12950
      RL = QIMAX - QIMIN                                               OPT12960
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```
      GO TO 7                                                          OPT12970
6     RL = QRMAX - QRMIN                                               OPT12980
7     B1 = .2*XAXIS                                                    OPT12990
      B2 = .5*XAXIS                                                    OPT13000
      B3 = XAXIS                                                       OPT13010
      C2 = .5*YAXIS                                                    OPT13020
      C3 = YAXIS                                                       OPT13030
      KK = 1                                                           OPT13040
      IF(RL.GT.B1) KK=2                                                OPT13050
      IF(RL.GT.B2) KK=3                                                OPT13060
      IF(RL.GT.B3) KK=4                                                OPT13070
      GO TO (11,12,13,14),KK                                           OPT13080
11    RL = B1                                                          OPT13090
      GO TO 16                                                         OPT13100
12    RL = B2                                                          OPT13110
      GO TO 16                                                         OPT13120
13    RL = B3                                                          OPT13130
      GO TO 16                                                         OPT13140
14    II = IFIX(RL)                                                    OPT13150
      N1 = IFIX(B2)                                                    OPT13160
17    J = MOD(II,N1)                                                   OPT13170
      IF(J.EQ.0) GO TO 21                                              OPT13180
      II = II+1                                                        OPT13190
      GO TO 17                                                         OPT13200
21    RSTEP = (FLOAT(II))/(FLOAT(N1))                                  OPT13210
      GO TO 18                                                         OPT13220
16    RSTEP = RL/B3                                                    OPT13230
18    IF(((QRMAX-QRMIN)/RSTEP).GE.B2) GO TO 22                         OPT13240
      XDIST = B2                                                       OPT13250
      GO TO 23                                                         OPT13260
22    XDIST = -QRMIN/RSTEP                                             OPT13270
23    IF(((QIMAX-QIMIN)/RSTEP).GE.C2) GO TO 24                         OPT13280
      YDIST = C2                                                       OPT13290
      GO TO 26                                                         OPT13300
24    YDIST = -QIMIN/RSTEP                                             OPT13310
26    IF(XDIST.GT.B3) XDIST = B3                                       OPT13320
      IF(YDIST.GT.C3) YDIST = C3                                       OPT13330
      THEFAC = 3.1415927/180.                                          OPT13340
C-----------------------------------------TEK 618-----------------------OPT13350
      IF(IPTR.EQ.2) GO TO 10                                           OPT13360
      CALL TEK618                                                      OPT13370
      CALL PAGE(PAGEX,PAGEY)                                           OPT13380
      CALL HWROT('AUTO')                                               OPT13390
      CALL HWSCAL('SCREEN')                                            OPT13400
      CALL NCBRDR                                                      OPT13410
      GO TO 20                                                         OPT13420
C-----------------------------------------COMPRS------------------------OPT13430
10    CONTINUE                                                         OPT13440
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      CALL CCMPRS                                                       OPT13450
      CALL PAGE(PAGEX,PAGEY)                                            OPT13460
20    CONTINUE                                                          OPT13470
C-----------------------------------------PLOT EXECUTION--------------OPT13480
      CALL NOCHEK                                                       OPT13490
      CALL GRACE(C.)                                                    OPT13500
      CALL PHYSOR(T1,T1)                                                OPT13510
      CALL AREA2D(XAXIS, YAXIS)                                         OPT13520
      CALL TRIPLX                                                       OPT13530
      CALL HEIGHT(TH)                                                   OPT13540
      CALL XNAME(' $',100)                                              OPT13550
      CALL HEIGHT(TH)                                                   OPT13560
      CALL YNAME(' $',100)                                              OPT13570
C-----------------------------------------POLAR PLOT-----------------OPT13580
      CALL POLAR(THEFAC,RSTEP,XDIST,YDIST)                              OPT13590
C-----------------------------------------HEADING--------------------OPT13600
      NN = NL + 1                                                       OPT13610
      IF(NL.EQ.0) GO TO 35                                              OPT13620
      DO 35 I=1,NL                                                      OPT13630
         CALL CLINE(I)                                                  OPT13640
         CALL HEADIN(LINE,100,T3,NN)                                    OPT13650
35    CONTINUE                                                          OPT13660
      IF(ITFX.EQ.1)                                                     OPT13670
     *   CALL HEADIN('OPEN LOOP TRANSFER NYQUIST$',100,T3,NN)           OPT13680
      IF(ITFX.EQ.2)                                                     OPT13690
     *   CALL HEADIN('NOISE TRANSFER NYQUIST$',100,T3,NN)               OPT13700
      IF(ITFX.EQ.3)                                                     OPT13710
     *   CALL HEADIN('COMPENSATOR TRANSFER NYQUIST$',100,T3,NN)         OPT13720
C-----------------------------------------AXIS PLOT------------------OPT13730
      XDO(1) = 0.C                                                      OPT13740
      XDO(2) = RL*2.0                                                   OPT13750
      YDO(1) = 0.C                                                      OPT13760
      YDO(2) = 0.C                                                      OPT13770
      DO 27 I = 1,4                                                     OPT13780
      CALL CURVE(YDO,XDO,2,0)                                           OPT13790
      YDO(1) = YDO(1) + 90.                                             OPT13800
27    CONTINUE                                                          OPT13810
C-----------------------------------------UNIT CIRCLE----------------OPT13820
      CALL DOT                                                          OPT13830
      CALL GRID(1,1)                                                    OPT13840
      XDO(1) = 0.C                                                      OPT13850
      YDO(1) = 1.C                                                      OPT13860
      DO 28 I = 2,360                                                   OPT13870
      XDO(I) = XDO(I-1) + 1.0                                           OPT13880
      YDO(I) = 1.C                                                      OPT13890
28    CONTINUE                                                          OPT13900
      CALL CURVE(XDO,YDO,360,0)                                         OPT13910
      CALL RESET('DOT')                                                 OPT13920
```

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C-----------------------------------------CURVE PLOT-----------------------OPT13930
      DO 29 I = 1,N                                                         OPT13940
      XNO(I) = SNGL(QPSR(I))                                                OPT13950
      YNO(I) = SNGL(MAG(I))                                                 OPT13960
29    CONTINUE                                                              OPT13970
      CALL CURVE(XNO,YNO,N,0)                                               OPT13980
      CALL FRAME                                                            OPT13990
C-----------------------------------------LEGEND--------------------------OPT14000
      XX = XAXIS - T7                                                       OPT14010
      YY = YAXIS + T8                                                       OPT14020
      CALL HEIGHT(TH1)                                                      OPT14030
      CALL MESSAG('INPUT # =    $',100,XX+T8,YY+T10)                        OPT14040
      CALL HEIGHT(TH1)                                                      OPT14050
      CALL INTNO(K1,'ABUT','ABUT')                                          OPT14060
      CALL HEIGHT(TH1)                                                      OPT14070
      CALL MESSAG('OUTPUT # =   $',100,XX+T8,YY+T9)                         OPT14080
      CALL HEIGHT(TH1)                                                      OPT14090
      CALL INTNO(K2,'ABUT','ABUT')                                          OPT14100
      CALL HEIGHT(TH1)                                                      OPT14110
      CALL MESSAG('DC GAIN =$',100,XX+T8,YY+T8)                             OPT14120
      CALL HEIGHT(TH1)                                                      OPT14130
      CALL REALNO(GOL,-3,'ABUT','ABUT')                                     OPT14140
      CALL BLREC(XX,YY,T5,T6,0.02)                                          OPT14150
C-----------------------------------------------------------------------OPT14160
      CALL ENDPL(0)                                                         OPT14170
      IF(IPTR.NE.2) GO TO 75                                                OPT14180
      CALL FRTCMS('CLRSCRN ')                                               OPT14190
      WRITE(6,130)                                                          OPT14200
C-----------------------------------GAIN AND PHASE MARGIN--------OPT14210
75    DO 73 I =1,N                                                          OPT14220
      OMEGA = DIMAG(WN(I))                                                  OPT14230
      XNO(I) = SNGL(OMEGA)                                                  OPT14240
      MA = 20.0*DLOG10(MAG(I))                                              OPT14250
      YNO(I) = SNGL(MA)                                                     OPT14260
      YDO(I) = SNGL(QPSR(I))                                                OPT14270
73    CONTINUE                                                              OPT14280
      CALL FRTCMS('CLRSCRN ')                                               OPT14290
      WRITE(6,135)                                                          OPT14300
C-----------------------------------------GAIN MARGIN--------------------OPT14310
      DO 71 I = 2,N                                                         OPT14320
      IF(ABS(YDO(I-1)).LT.180.0.AND.ABS(YDO(I)).GE.180.0) GO TO 72          OPT14330
      IF(ABS(YDO(I-1)).GT.180.0.AND.ABS(YDO(I)).LE.180.0) GO TO 72          OPT14340
      GO TO 71                                                              OPT14350
72    GM = 0.0 - YNO(I)                                                     OPT14360
      WRITE (6,140) XNO(I), GM                                              OPT14370
71    CONTINUE                                                              OPT14380
C-----------------------------------------PHASE MARGIN-------------------OPT14390
      DO 76 I = 2,N                                                         OPT14400
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      IF(YNO(I-1).GT.0.0.AND.YNO(I).LE.0.0) GO TO 77                    OPT14410
      GO TO 76                                                          OPT14420
77    PM = 180.0 + YDO(I)                                               OPT14430
      WRITE (6,150) XNO(I), PM                                          OPT14440
76    CONTINUE                                                          OPT14450
      WRITE(6,160)                                                      OPT14460
C-----------------------------------------CHANGES TO PLOT--------------OPT14470
90    CONTINUE                                                          OPT14480
      CALL FRTCMS('CLRSCRN ')                                           OPT14490
      WRITE(6,120)                                                      OPT14500
      IF(ITEX.EQ.1) WRITE(6,710)                                        OPT14510
      IF(ITEX.EQ.2) WRITE(6,711)                                        OPT14520
      IF(ITEX.EQ.3) WRITE(6,712)                                        OPT14530
      WRITE(6,100)                                                      OPT14540
30    WRITE(6,110)                                                      OPT14550
      CALL RDINT(IANS)                                                  OPT14560
      IF(IANS.GT.5.OR.IANS.LT.1) GO TO 15                               OPT14570
      GO TO 25                                                          OPT14580
15    WRITE(6,510)                                                      OPT14590
      GO TO 30                                                          OPT14600
25    CONTINUE                                                          OPT14610
      ICHG = 1                                                          OPT14620
      GO TO (40,50,60,70,200),IANS                                      OPT14630
C-----------------------------------------TABULAR DATA----------------OPT14640
202   CONTINUE                                                          OPT14650
      IF(GAN(2,K2,K1).EQ.0.0) GO TO 95                                  OPT14660
      ICHG =0                                                           OPT14670
251   CALL FRTCMS('CLRSCRN ')                                           OPT14680
      IF(ICHG.EQ.1) GO TO 249                                           OPT14690
      WRITE(6,120)                                                      OPT14700
      IF(ITEX.EQ.1) WRITE(6,710)                                        OPT14710
      IF(ITEX.EQ.2) WRITE(6,711)                                        OPT14720
      IF(ITEX.EQ.3) WRITE(6,712)                                        OPT14730
249   CALL PRTR(IPT)                                                    OPT14740
      IF(ICHG.EQ.1) GO TO 290                                           OPT14750
252   CALL FRTCMS('CLRSCRN ')                                           OPT14760
      CALL FGRAF(FMIN,FMAX)                                             OPT14770
      IF(ICHG.EQ.1) GO TO 290                                           OPT14780
253   CALL FRTCMS('CLRSCRN ')                                           OPT14790
      CALL NPTS(PTS)                                                    OPT14800
      IF(ICHG.EQ.1) GO TO 290                                           OPT14810
C-----------------------------------------TABULATE DATA----------------OPT14820
254   CONTINUE                                                          OPT14830
      ZERO = 0.0                                                        OPT14840
      J1 = 0                                                            OPT14850
      CRD = DINT(GAN(1,K2,K1))                                          OPT14860
      GAIN = GAN(2,K2,K1)                                               OPT14870
      CALL FRTCMS('CLRSCRN ')                                           OPT14880
```

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      WRITE(IPT,120)                                                    OPT14890
      IF(ITFX.EQ.1) WRITE(IPT,710)                                      OPT14900
      IF(ITFX.EQ.2) WRITE(IPT,711)                                      OPT14910
      IF(ITFX.EQ.3) WRITE(IPT,712)                                      OPT14920
      WRITE(IPT,300) K1                                                 OPT14930
      WRITE(IPT,301) K2                                                 OPT14940
      WRITE(IPT,311) NS                                                 OPT14950
      WRITE(IPT,310) ORD                                                OPT14960
      WRITE(IPT,320) GAN(2,K2,K1)                                       OPT14970
      WRITE(IPT,350)                                                    OPT14980
      N = PTS                                                           OPT14990
      CALL FREQ(NS,K2,K1,FMIN,FMAX,N)                                   OPT15000
      DO 220 I = 1,N                                                    OPT15010
      OMEGA = DIMAG(WN(I))                                              OPT15020
      WRITE(IPT,330) OMEGA,MAG(I),QPSR(I),QR(I),QI(I)                   OPT15030
220   CONTINUE                                                          OPT15040
C-----------------------------------------CHANGES TABULAR DATA---------OPT15050
240   IF(IPT.EQ.3) WRITE (6,401)                                        OPT15060
      IF(IPT.EQ.2) WRITE (6,402)                                        OPT15070
      WRITE(6,400)                                                      OPT15080
      CALL RDCHAR (IANS)                                                OPT15090
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 245                      OPT15100
      GO TO 250                                                         OPT15110
245   WRITE (6,500)                                                     OPT15120
      GO TO 240                                                         OPT15130
250   CONTINUE                                                          OPT15140
      IF (IANS.EQ.IY) GO TO 290                                         OPT15150
      IF (IANS.EQ.IZ) GO TO 200                                         OPT15160
C-----------------------------------------CHANGES ---------------------OPT15170
290   CONTINUE                                                          OPT15180
      CALL FRTCMS('CLRSCRN ')                                           OPT15190
      WRITE(6,120)                                                      OPT15200
      IF(ITFX.EQ.1) WRITE(6,710)                                        OPT15210
      IF(ITFX.EQ.2) WRITE(6,711)                                        OPT15220
      IF(ITFX.EQ.3) WRITE(6,712)                                        OPT15230
      WRITE(6,410)                                                      OPT15240
291   WRITE(6,110)                                                      OPT15250
      CALL RDINT(IANS)                                                  OPT15260
      IF(IANS.GT.5.OR.IANS.LT.1) GO TO 292                              OPT15270
      GO TO 293                                                         OPT15280
292   WRITE(6,510)                                                      OPT15290
      GO TO 291                                                         OPT15300
293   CONTINUE                                                          OPT15310
      ICHG = 1                                                          OPT15320
      GO TO (251,252,253,254,200),IANS                                  OPT15330
C-----------------------------------------------------------------------OPT15340
60    RETURN                                                            OPT15350
95    WRITE(6,520)                                                      OPT15360
```

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      RETURN                                                                OPT15270
C-----------------------------------------------------------------------OPT15380
100   FORMAT(//,5X,'DO YOU DESIRE TO MAKE ANY CHANGES TO:',//,10X,'1.  POPT15390
     *LOTTER / PAGE SIZE',/,10X,'2.  FREQUENCY RANGE',/,10X,'3.  HEADINGOPT15400
     *',/,10X,'4.  NO ADDITIONAL CHANGES - PLOT NYQUIST PLOTS',/,10X,   OPT15410
     *'5.  NO CHANGES - EXIT NYQUIST PLOTTING ROUTINE',/)               OPT15420
110   FORMAT(/,5X,'ENTER OPTION NUMBER.',/)                             OPT15430
120   FORMAT(//,15X,'NYQUIST PLOT')                                     OPT15440
130   FORMAT(/////////,15X,'A DISSPLA METAFILE HAS BEEN CREATED',/,     OPT15450
     *15X,'CLEAR SCREEN TO CONTINUE',////////////////////)              OPT15460
135   FORMAT(////,15X,'GAIN MARGIN AND PHASE MARGIN',/)                 OPT15470
140   FORMAT(/,3X,'PHASE CROSSOVER FREQUENCY IS',F10.4,' RAD/SEC;'1X,   OPT15480
     *'GAIN MARGIN IS ',F10.4,' DB')                                   OPT15490
150   FORMAT(/,3X,'GAIN CROSSOVER FREQUENCY IS ',F10.4,' RAD/SEC;',1X,  OPT15500
     *,'PHASE MARGIN IS',F10.4,' DEG')                                 OPT15510
160   FORMAT(//,15X,'CLEAR SCREEN TO CONTINUE',////////////////////)    OPT15520
300   FORMAT(//,10X,'INPUT NUMBER =     ',I5)                           OPT15530
301   FORMAT(10X,'OUTPUT NUMBER =     ',I5)                             OPT15540
310   FORMAT(10X,'NUMERATOR ORDER =   ',I5)                             OPT15550
311   FORMAT(10X,'DENOMINATOR ORDER =',I5)                              OPT15560
320   FORMAT(10X,'TRANSFER FUNCTION (DC) GAIN =',D12.4,/)               OPT15570
330   FORMAT(5X,D12.4,3X,D12.4,3X,D12.4,3X,D12.4,3X,D12.4)              OPT15580
350   FORMAT(5X,'  FREQUENCY ',3X,'  MAGNITUDE ',3X,' PHASE     ',     OPT15590
     * 3X,'     REAL     ',3X,'    IMAGINARY',                         OPT15600
     */,5X,'   (RAD/SEC)  ',3X,'              ',3X,' (DEGREES)',      OPT15610
     * 3X,'     PART     ',3X,'     PART     ')                       OPT15620
400   FORMAT (/,5X,'DO YOU DESIRE TO MAKE ANY CHANGES ?',/,             OPT15630
     *10X,'TYPE "YES" OR "NO".',/)                                     OPT15640
401   FORMAT(////,5X,'OUTPUT SENT TO PRINTER',/)                        OPT15650
402   FORMAT(////,5X,'OUTPUT SENT TO LISTING FILE',/)                   OPT15660
410   FORMAT(//,5X,'DO YOU DESIRE TO MAKE ANY CHANGES TO:',//,          OPT15670
     *10X,'1.  OUTPUT DEVICE',/,                                       OPT15680
     *10X,'2.  FREQUENCY RANGE',/,                                     OPT15690
     *10X,'3.  NUMBER OF POINTS CALCULATED',/,                         OPT15700
     *10X,'4.  NO ADDITIONAL CHANGES - TABULATE DATA',/,               OPT15710
     *10X,'5.  EXIT NYQUIST TABULAR DATA ROUTINE',/)                   OPT15720
500   FORMAT(/,5X,'****** WARNING *****',/,5X,'IMPROPER DATA ENTRY   ', OPT15730
     *3X,'ENTER "YES" OR "NO".',/)                                     OPT15740
501   FORMAT(/,5X,'****** WARNING *****',/,5X,'IMPROPER DATA ENTRY   ', OPT15750
     *3X,'ENTER "YES" TO CONTINUE',/)                                  OPT15760
510   FORMAT(/,5X,'****** ERROR ******',10X,'IMPROPER DATA ENTRY',/)    OPT15770
520   FORMAT(/,5X,'****** WARNING ******',10X,'NUMERATOR IS EQUAL TO ZERPT15780
     *O',/)                                                            OPT15790
710   FORMAT (5X,'OPEN LOOP TRANSFER FUNCTION',/)                       OPT15800
711   FORMAT (5X,'NOISE TRANSFER FUNCTION',/)                           OPT15810
712   FORMAT (5X,'COMPENSATOR TRANSFER FUNCTION',/)                     OPT15820
C-----------------------------------------------------------------------OPT15830
      END                                                               OPT15840
```

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C=====================================================================OPT15850
C=====================================================================OPT15860
      SUBROUTINE NICHOL (NS,K2,K1,ITFX)                               OPT15870
C     INTERATIVELY PLOTS A NICHOLS PLOT USING DISSPLA GRAPHICS GIVEN  OPT15880
C     THE ZERO AND POLE LOCATIONS                                     OPT15890
C=====================================================================OPT15900
      REAL*8 OLN,OLD,ORNUM,QI,QR,QPSR,MAG,GAN,CC,MA,OMEGA             OPT15910
      REAL*4 XDO,YDO,XNO,YNO,FMIN,FMAX,MMIN,MMAX,XAXIS,YAXIS,PAGEX,   OPT15920
     *PAGEY,XX,YY,GOL,FL,FU,PM,GM,C2,C3,TS,TH,T1,T2,T3,T4,T5,T6,T7,T8,OPT15930
     *PMIN,PMAX,RL,B1,B2,B3,TH1,T9,T10                                 OPT15940
      COMPLEX*16 RTN,PLN,RTD,PLD,WN                                   OPT15950
      INTEGER NS,IPTR,K1,K2,NN,NL,LINES,IANS,ICHG,LINE,N,IPP,CRD,PTS, OPT15960
     *KK,J,II,N1,IPT,ITFX                                             OPT15970
      COMMON /GRAFF/ OLN(99,2,12,12),OLD(99,2),GAN(2,12,12),CC        OPT15980
      COMMON /SGRAF/ XDO(500),YDO(500),XNO(500),YNO(500)              OPT15990
      COMMON /SHEAD/ LINES(4,18),LINE(9)                              OPT16000
      COMMON /FFREQ/ RTN(99),PLN(99),RTD(99),PLD(99),WN(500),QI(500), OPT16010
     *QR(500),QPSR(500),MAG(500)                                      OPT16020
      COMMON /SCALE/ TS,TH,TH1,T1,T2,T3,T4,T5,T6,T7,T8,T9,T10         OPT16030
      DATA IY/'Y'/,IZ/'N'/                                            OPT16040
C----------------------GRAPHIC OR TABULAR OUTPUT----------------------OPT16050
200   CALL FRTCMS('CLRSCRN ')                                         OPT16060
      WRITE(6,120)                                                    OPT16070
      IF(ITFX.EQ.1) WRITE(6,710)                                      OPT16080
      IF(ITFX.EQ.2) WRITE(6,711)                                      OPT16090
      IF(ITFX.EQ.3) WRITE(6,712)                                      OPT16100
      CALL PRTPLT(IPP)                                                OPT16110
      GO TO (201,202,80),IPP                                          OPT16120
C-----------------------------------------PLOT SETUP------------------OPT16130
201   CONTINUE                                                        OPT16140
      N = 500                                                         OPT16150
      ICHG = 0                                                        OPT16160
      IF(GAN(2,K2,K1).EQ.0.0) GO TO 95                                OPT16170
40    CALL FRTCMS('CLRSCRN ')                                         OPT16180
      IF(ICHG.EQ.1) GO TO 41                                          OPT16190
      WRITE (6,120)                                                   OPT16200
      IF(ITFX.EQ.1) WRITE(6,710)                                      OPT16210
      IF(ITFX.EQ.2) WRITE(6,711)                                      OPT16220
      IF(ITFX.EQ.3) WRITE(6,712)                                      OPT16230
41    CALL GSETUP(IPTR,PAGEX,PAGEY)                                   OPT16240
      IF(ICHG.EQ.1) GO TO 90                                          OPT16250
50    CALL FRTCMS('CLRSCRN ')                                         OPT16260
      CALL FGRAF(FMIN,FMAX)                                           OPT16270
      IF(ICHG.EQ.1) GO TO 90                                          OPT16280
60    CALL FRTCMS('CLRSCRN ')                                         OPT16290
      CALL GHEAD(NL)                                                  OPT16300
      IF(ICHG.EQ.1) GO TO 90                                          OPT16310
70    CONTINUE                                                        OPT16320
```

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C-----------------------------------------SCALING CONSTANTS-----------OPT16330
      CALL PSCALE(PAGEX)                                               OPT16340
C-----------------------------------------INPUT ARRAYS----------------OPT16350
      GOL  = SNGL(GAN(2,K2,K1))                                        OPT16360
      CALL FREQ(NS,K2,K1,FMIN,FMAX,N)                                  OPT16370
      DO 5 I =1,N                                                      OPT16380
      MA = 20.0*DLOG10(MAG(I))                                         OPT16390
      YDO(I) = SNGL(MA)                                                OPT16400
      XDO(I) = SNGL(QPSR(I))                                           OPT16410
5     CONTINUE                                                         OPT16420
      CALL MINMAX(N,YDO,MMIN,MMAX)                                     OPT16430
      CALL MINMAX(N,XDO,PMIN,PMAX)                                     OPT16440
C-----------------------------------------PLOT LIMITS-----------------OPT16450
      XAXIS = PAGEX -2.*T1                                             OPT16460
      YAXIS = PAGEY -T1 -T2                                            OPT16470
      IF(MMAX.LT.C.0) MMAX = 0.0                                       OPT16480
      IF(MMIN.GT.C.0) MMIN = 0.0                                       OPT16490
      IF(PMAX.LT.0.0) PMAX = 0.0                                       OPT16500
      IF(PMIN.GT.C.0) PMIN = 0.0                                       OPT16510
C-----------------------------------------TEK 618--------------------OPT16520
      IF(IPTR.EQ.2) GO TO 10                                           OPT16530
      CALL TEK618                                                      OPT16540
      CALL PAGE(PAGEX,PAGEY)                                           OPT16550
      CALL HWROT('AUTO')                                               OPT16560
      CALL HWSCAL('SCREEN')                                            OPT16570
      CALL NCBRDR                                                      OPT16580
      GO TO 20                                                         OPT16590
C-----------------------------------------COMPRS---------------------OPT16600
10    CONTINUE                                                         OPT16610
      CALL CCMPRS                                                      OPT16620
      CALL PAGE(PAGEX,PAGEY)                                           OPT16630
20    CONTINUE                                                         OPT16640
C-----------------------------------------PLOT EXECUTION--------------OPT16650
      CALL NCCHEK                                                      OPT16660
      CALL GRACE(C.)                                                   OPT16670
      CALL PHYSOR(T1,T1)                                               OPT16680
      CALL AREA2D(XAXIS, YAXIS)                                        OPT16690
      CALL TRIPLX                                                      OPT16700
      CALL HEIGHT(TH)                                                  OPT16710
      CALL XNAME('PHASE - DEGREES $',100)                              OPT16720
      CALL HEIGHT(TH)                                                  OPT16730
      CALL YNAME('MAGNITUDE - DECIBELS $',100)                         OPT16740
      CALL GRAF(PMIN,'SCALE',PMAX,MMIN,'SCALE',MMAX)                   OPT16750
C-----------------------------------------HEADING--------------------OPT16760
      NN = NL + 1                                                      OPT16770
      IF(NL.EQ.0) GO TO 35                                             OPT16780
      DO 35 I=1,NL                                                     OPT16790
         CALL CLINE(I)                                                 OPT16800
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      CALL HEADIN(LINE,100,T3,NN)                                       OPT16810
35    CONTINUE                                                          OPT16820
      IF(ITFX.EQ.1)                                                     OPT16830
     *   CALL HEADIN('OPEN LOOP TRANSFER NICHOLS$',100,T3,NN)           OPT16840
      IF(ITFX.EQ.2)                                                     OPT16850
     *   CALL HEADIN('NOISE TRANSFER NICHOLS$',100,T3,NN)               OPT16860
      IF(ITFX.EQ.3)                                                     OPT16870
     *   CALL HEADIN('COMPENSATOR TRANSFER NICHOLS$',100,T3,NN)         OPT16880
C-----------------------------------------CURVE PLOT-------------------OPT16890
      CALL CURVE(XDO,YDO,N,0)                                           OPT16900
C-----------------------------------------LEGEND----------------------OPT16910
      XX = XAXIS - T7                                                   OPT16920
      YY = YAXIS + T8                                                   OPT16930
      CALL HEIGHT(TH1)                                                  OPT16940
      CALL MESSAG('INPUT # =     $',100,XX+T8,YY+T10)                   OPT16950
      CALL HEIGHT(TH1)                                                  OPT16960
      CALL INTNO(K1,'ABUT','ABUT')                                      OPT16970
      CALL HEIGHT(TH1)                                                  OPT16980
      CALL MESSAG('OUTPUT # =    $',100,XX+T8,YY+T9)                    OPT16990
      CALL HEIGHT(TH1)                                                  OPT17000
      CALL INTNO(K2,'ABUT','ABUT')                                      OPT17010
      CALL HEIGHT(TH1)                                                  OPT17020
      CALL MESSAG('DC GAIN =$',100,XX+T8,YY+T8)                         OPT17030
      CALL HEIGHT(TH1)                                                  OPT17040
      CALL REALNO(GOL,-3,'ABUT','ABUT')                                 OPT17050
      CALL BLREC(XX,YY,T5,T6,0.02)                                      OPT17060
C-----------------------------------------------------------------------OPT17070
C-----------------------------------------GRID------------------------OPT17080
      CALL DOT                                                          OPT17090
      CALL GRID(1,1)                                                    OPT17100
      CALL RESET('DOT')                                                 OPT17110
      CALL ENDPL(0)                                                     OPT17120
      IF(IPTR.NE.2) GO TO 75                                            OPT17130
      CALL FRTCMS('CLRSCRN ')                                           OPT17140
      WRITE(6,130)                                                      OPT17150
C-----------------------------------------GAIN AND PHASE MARGIN--------OPT17160
75    DO 73 I =1,N                                                      OPT17170
      OMEGA = DIMAG(WN(I))                                              OPT17180
      XNO(I) = SNGL(OMEGA)                                              OPT17190
      MA = 20.0*DLOG10(MAG(I))                                          OPT17200
      YNO(I) = SNGL(MA)                                                 OPT17210
      YDO(I) = SNGL(QPSR(I))                                            OPT17220
73    CONTINUE                                                          OPT17230
      CALL FRTCMS('CLRSCRN ')                                           OPT17240
      WRITE(6,135)                                                      OPT17250
C-----------------------------------------GAIN MARGIN------------------OPT17260
      DO 71 I = 2,N                                                     OPT17270
      IF(ABS(YDO(I-1)).LT.180.0.AND.ABS(YDO(I)).GE.180.0) GO TO 72      OPT17280
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      IF(ABS(YDO(I-1)).GT.180.0.AND.ABS(YDO(I)).LE.180.0) GO TO 72      OPT17290
      GO TO 71                                                          OPT17300
72    GM = 0.0 - YNO(I)                                                 OPT17310
      WRITE (6,140) XNO(I), GM                                          OPT17320
71    CONTINUE                                                          OPT17330
C-----------------------------------------PHASE MARGIN-----------------OPT17340
      DO 76 I = 2,N                                                     OPT17350
      IF(YNO(I-1).GT.0.0.AND.YNO(I).LE.0.0) GO TO 77                    OPT17360
      GO TO 76                                                          OPT17370
77    PM = 180.0 + YDO(I)                                               OPT17380
      WRITE (6,150) XNO(I), PM                                          OPT17390
76    CONTINUE                                                          OPT17400
      WRITE(6,160)                                                      OPT17410
C-----------------------------------------CHANGES TO PLOT--------------OPT17420
90    CONTINUE                                                          OPT17430
      CALL FRTCMS('CLRSCRN ')                                           OPT17440
      WRITE(6,120)                                                      OPT17450
      IF(ITEX.EQ.1) WRITE(6,710)                                        OPT17460
      IF(ITEX.EQ.2) WRITE(6,711)                                        OPT17470
      IF(ITEX.EQ.3) WRITE(6,712)                                        OPT17480
      WRITE(6,100)                                                      OPT17490
30    WRITE(6,110)                                                      OPT17500
      CALL RDINT(IANS)                                                  OPT17510
      IF(IANS.GT.5.OR.IANS.LT.1) GO TO 15                               OPT17520
      GO TO 25                                                          OPT17530
15    WRITE(6,510)                                                      OPT17540
      GO TO 30                                                          OPT17550
25    CONTINUE                                                          OPT17560
      ICHG = 1                                                          OPT17570
      GO TO (40,50,60,70,200),IANS                                      OPT17580
C-----------------------------------------TABULAR DATA----------------OPT17590
202   CONTINUE                                                          OPT17600
      IF(GAN(2,K2,K1).EQ.0.0) GO TO 95                                  OPT17610
      ICHG =0                                                           OPT17620
251   CALL FRTCMS('CLRSCRN ')                                           OPT17630
      IF(ICHG.EQ.1) GO TO 249                                           OPT17640
      WRITE(6,120)                                                      OPT17650
      IF(ITEX.EQ.1) WRITE(6,710)                                        OPT17660
      IF(ITEX.EQ.2) WRITE(6,711)                                        OPT17670
      IF(ITEX.EQ.3) WRITE(6,712)                                        OPT17680
249   CALL PRTR(IPT)                                                    OPT17690
      IF(ICHG.EQ.1) GO TO 290                                           OPT17700
252   CALL FRTCMS('CLRSCRN ')                                           OPT17710
      CALL FGRAF(FMIN,FMAX)                                             OPT17720
      IF(ICHG.EQ.1) GO TO 290                                           OPT17730
253   CALL FRTCMS('CLRSCRN ')                                           OPT17740
      CALL NPTS(PTS)                                                    OPT17750
      IF(ICHG.EQ.1) GO TO 290                                           OPT17760
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C-----------------------------------------TABULATE DATA-----------------OPT17770
254   CONTINUE                                                          OPT17780
      ZERO = 0.0                                                        OPT17790
      J1 = 0                                                            OPT17800
      ORD = DINT(GAN(1,K2,K1))                                          OPT17810
      GAIN = GAN(2,K2,K1)                                               OPT17820
      CALL FRTCMS('CLRSCRN ')                                           OPT17830
      WRITE(IPT,120)                                                    OPT17840
      IF(ITFX.EQ.1) WRITE(IPT,710)                                      OPT17850
      IF(ITFX.EQ.2) WRITE(IPT,711)                                      OPT17860
      IF(ITFX.EQ.3) WRITE(IPT,712)                                      OPT17870
      WRITE(IPT,300) K1                                                 OPT17880
      WRITE(IPT,301) K2                                                 OPT17890
      WRITE(IPT,311) NS                                                 OPT17900
      WRITE(IPT,310) ORD                                                OPT17910
      WRITE(IPT,320) GAN(2,K2,K1)                                       OPT17920
      WRITE(IPT,350)                                                    OPT17930
      N = PTS                                                           OPT17940
      CALL FREQ(NS,K2,K1,FMIN,FMAX,N)                                   OPT17950
      DO 220 I = 1,N                                                    OPT17960
      OMEGA = DIMAG(WN(I))                                              OPT17970
      MA = 20.0*DLOG10(MAG(I))                                          OPT17980
      WRITE(IPT,330) OMEGA,MA,QPSR(I),QR(I),QI(I)                       OPT17990
220   CONTINUE                                                          OPT18000
C-----------------------------------------CHANGES TABULAR DATA---------OPT18010
240   IF(IPT.EQ.3) WRITE (6,401)                                        OPT18020
      IF(IPT.EQ.2) WRITE (6,402)                                        OPT18030
      WRITE(6,400)                                                      OPT18040
      CALL RDCHAR (IANS)                                                OPT18050
      IF ((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 245                      OPT18060
      GO TO 250                                                         OPT18070
245   WRITE (6,500)                                                     OPT18080
      GO TO 240                                                         OPT18090
250   CONTINUE                                                          OPT18100
      IF (IANS.EQ.IY) GO TO 290                                         OPT18110
      IF (IANS.EQ.IZ) GO TO 200                                         OPT18120
C-----------------------------------------CHANGES ----------------------OPT18130
290   CONTINUE                                                          OPT18140
      CALL FRTCMS('CLRSCRN ')                                           OPT18150
      WRITE(6,120)                                                      OPT18160
      IF(ITFX.EQ.1) WRITE(6,710)                                        OPT18170
      IF(ITFX.EQ.2) WRITE(6,711)                                        OPT18180
      IF(ITFX.EQ.3) WRITE(6,712)                                        OPT18190
      WRITE(6,410)                                                      OPT18200
291   WRITE(6,110)                                                      OPT18210
      CALL RDINT(IANS)                                                  OPT18220
      IF(IANS.GT.5.OR.IANS.LT.1) GO TO 292                              OPT18230
      GO TO 293                                                         OPT18240
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292   WRITE(6,510)                                                    OPT18250
      GO TO 291                                                       OPT18260
293   CONTINUE                                                        OPT18270
      ICHG = 1                                                        OPT18280
      GO TO (251,252,253,254,200),IANS                                OPT18290
C-----------------------------------------------------------------OPT18300
80    RETURN                                                          OPT18310
95    WRITE(6,520)                                                    OPT18320
      RETURN                                                          OPT18330
C-----------------------------------------------------------------OPT18340
100   FORMAT(//,5X,'DO YOU DESIRE TO MAKE ANY CHANGES TO:',//,10X,'1.  POPT18350
     *LOTTER / PAGE SIZE',/,10X,'2.  FREQUENCY RANGE',/,10X,'3.  HEADINGOPT18360
     *',/,10X,'4.  NO ADDITIONAL CHANGES - PLOT NICHOLS PLOTS',/,10X,  OPT18370
     *'5.  NO CHANGES - EXIT NICHOLS PLOTTING ROUTINE',/)              OPT18380
110   FORMAT(/,5X,'ENTER OPTION NUMBER.',/)                           OPT18390
120   FORMAT(//,15X,'NICHOLS PLOT')                                   OPT18400
130   FORMAT(/////////,15X,'A DISSPLA METAFILE HAS BEEN CREATED',/,   OPT18410
     *15X,'CLEAR SCREEN TO CONTINUE',//////////////////////)          OPT18420
135   FORMAT(////,15X,'GAIN MARGIN AND PHASE MARGIN',/)               OPT18430
140   FORMAT(/,3X,'PHASE CROSSOVER FREQUENCY IS',F10.4,' RAD/SEC;'1X, OPT18440
     *'GAIN MARGIN IS ',F10.4,' DB')                                  OPT18450
150   FORMAT(/,3X,'GAIN CROSSOVER FREQUENCY IS ',F10.4,' RAD/SEC;',1X,OPT18460
     *,'PHASE MARGIN IS',F10.4,' DEG')                                OPT18470
160   FORMAT(//,15X,'CLEAR SCREEN TO CONTINUE',//////////////////////) OPT18480
200   FORMAT(//,10X,'INPUT NUMBER =      ',I5)                        OPT18490
301   FORMAT(10X,'OUTPUT NUMBER =    ',I5)                           OPT18500
310   FORMAT(10X,'NUMERATOR ORDER =  ',I5)                           OPT18510
311   FORMAT(10X,'DENOMINATOR ORDER =',I5)                           OPT18520
320   FORMAT(10X,'TRANSFER FUNCTION GAIN =',D12.4,/)                 OPT18530
330   FORMAT(5X,D12.4,3X,D12.4,3X,D12.4,3X,D12.4,3X,D12.4)           OPT18540
350   FORMAT(5X,'  FREQUENCY ',3X,'  MAGNITUDE ',3X,' PHASE     ',   OPT18550
     * 3X,'     REAL     ',3X,'    IMAGINARY',                       OPT18560
     */,5X,'  (RAD/SEC)  ',3X,'              ',3X,' (DEGREES)',     OPT18570
     * 3X,'      PART    ',3X,'     PART     ')                      OPT18580
400   FORMAT (/,5X,'DO YOU DESIRE TO MAKE ANY CHANGES ?',/,           OPT18590
     *10X,'TYPE "YES" OR "NO".',/)                                   OPT18600
401   FORMAT(////,5X,'OUTPUT SENT TO PRINTER',/)                      OPT18610
402   FORMAT(////,5X,'OUTPUT SENT TO LISTING FILE',/)                 OPT18620
410   FORMAT(//,5X,'DO YOU DESIRE TO MAKE ANY CHANGES TO:',//,        OPT18630
     *10X,'1.  OUTPUT DEVICE',/,                                     OPT18640
     *10X,'2.  FREQUENCY RANGE',/,                                   OPT18650
     *10X,'3.  NUMBER OF POINTS CALCULATED',/,                       OPT18660
     *10X,'4.  NO ADDITIONAL CHANGES - TABULATE DATA',/,             OPT18670
     *10X,'5.  EXIT BODE TABULAR DATA ROUTINE',/)                    OPT18680
500   FORMAT(/,5X,'****** WARNING ******',/,5X,'IMPROPER DATA ENTRY   ', OPT18690
     *3X,'ENTER "YES" OR "NO".',/)                                   OPT18700
501   FORMAT(/,5X,'****** WARNING ******',/,5X,'IMPROPER DATA ENTRY   ', OPT18710
     *3X,'ENTER "YES" TO CONTINUE',/)                                OPT18720
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510   FORMAT(/,5X,'****** ERROR ******',10X,'IMPPOPER DATA ENTRY',/)     OPT18730
520   FORMAT(/,5X,'****** WARNING ******',10X,'NUMERATOR IS EQUAL TC ZEROPT18740
     *C',/)                                                             OPT18750
710   FORMAT (5X,'OPEN LOOP TRANSFER FUNCTION',/)                       OPT18760
711   FORMAT (5X,'NOISE TRANSFER FUNCTION',/)                           OPT18770
712   FORMAT (5X,'COMPENSATOR TRANSFER FUNCTION',/)                     OPT18780
C-----------------------------------------------------------------------OPT18790
      END                                                               OPT18800
C=======================================================================OPT18810
C=======================================================================OPT18820
      SUBROUTINE FREQ(NS,K2,K1,FMIN,FMAX,NN)                            OPT18830
C     THE SUBROUTINE FREQ CALCULATES THE MAGNITUDE AND PHASE FOR THE    OPT18840
C     BODE, NYQUIST, AND NICHOLS RESPONSES                              OPT18850
C=======================================================================OPT18860
      REAL*8 OLD,CLN,MAG,QI,QR,QPSR,FRMAX,FRMIN,CYCLE,ZERO,XX,AA,GAIN,  OPT18870
     *DELTF,GAN,CC                                                      OPT18880
      REAL*4 FMAX, FMIN                                                 OPT18890
      COMPLEX*16 RTN,PLN,RTD,PLD,CPOLN,WN,CPOLD,CPOL                    OPT18900
      INTEGER I,J1,K2,K1,NS,IPHS,JJ,L,N,N1,N2,NN,ORD                    OPT18910
      COMMON /GRAFF/ OLN(99,2,12,12),OLD(99,2),GAN(2,12,12),CC          OPT18920
      COMMON /FFREQ/ RTN(99),PLN(99),RTD(99),PLD(99),WN(500),QI(500),   OPT18930
     *QR(500),QPSR(500),MAG(500)                                        OPT18940
C-----------------------------------------------------------------------OPT18950
C-------------------------------------NUMERATOR / DENOMINATOR-----------OPT18960
      AA = DFLOAT(NN)                                                   OPT18970
      J1= 0                                                             OPT18980
      DO 4 I = 1,NS                                                     OPT18990
      RTN(I) = 0.0                                                      OPT19000
      RTD(I) =0.0                                                       OPT19010
4     CONTINUE                                                          OPT19020
      DO 10 I = 1,NS                                                    OPT19030
      IF((DABS(OLN(I,1,K2,K1)).LE.CO).AND.(DABS(CLN(I,2,K2,K1)).LE.CO)) OPT19040
     * GO TO 20                                                         OPT19050
      J1= J1+1                                                          OPT19060
      RTN(J1) = DCMPLX(OLN(I,1,K2,K1),OLN(I,2,K2,K1))                   OPT19070
2C    CONTINUE                                                          OPT19080
      RTD(I) = DCMPLX(OLD(I,1),OLD(I,2))                                OPT19090
10    CONTINUE                                                          OPT19100
      ORD = DINT(GAN(1,K2,K1))                                          OPT19110
      IF(ORD.GT.J1) J1 = ORD                                            OPT19120
C-------------------------------------TRANSFER FUNCTION MATH ------OPT19130
      ZERO = 0.0                                                        OPT19140
      GAIN = GAN(2,K2,K1)                                               OPT19150
      IPHS = 0                                                          OPT19160
C-------------------------------------INCREMENT FREQUENCY----------OPT19170
      FRMAX = DBLE(FMAX)                                                OPT19180
      FRMIN = DBLE(FMIN)                                                OPT19190
      CYCLE = (DLOG10(FRMAX) - DLOG10(FRMIN))/(AA - 1.)                 OPT19200
```

```
      DELTF = 10.**CYCLE                                                OPT19210
      DO 80 I = 1,NN                                                    OPT19220
      IF(I.GT.1)GO TO 5                                                 OPT19230
      WN(1) = DCMPLX(ZERO,FRMIN)                                        OPT19240
      GO TO 6                                                           OPT19250
5     WN(I) = WN(I-1) * DELTF                                           OPT19260
C-----------------------------------------POLYNOMIAL--------------------OPT19270
6     CPOL = 1.                                                         OPT19280
      IF(J1.EQ.0) GO TO 7                                               OPT19290
      DO 30 K = 1,J1                                                    OPT19300
30    CPOL = CPOL*(WN(I)-RTN(K))/(WN(I)-RTD(K))                         OPT19310
      IF(J1.EQ.NS) GO TO 8                                              OPT19320
7     JJ = J1 + 1                                                       OPT19330
9     DO 40 K = JJ,NS                                                   OPT19340
40    CPOL = CPOL/(WN(I)-RTD(K))                                        OPT19350
8     CPOL = CPOL*GAIN                                                  OPT19360
C-----------------------------------------MAGNITUDE--------------------OPT19370
      MAG(I) = CDABS(CPOL)                                              OPT19380
C-----------------------------------------PHASE------------------------OPT19390
      QI(I) = DIMAG(CPOL)                                               OPT19400
      QR(I) = DREAL(CPOL)                                               OPT19410
600   IF(QI(I)) 601,602,603                                             OPT19420
601   IF(QR(I)) 620,621,622                                             OPT19430
602   IF(QR(I)) 623,751,625                                             OPT19440
603   IF(QR(I)) 626,627,628                                             OPT19450
620   QPSR(I) = -180.+ 57.29577951*DATAN(QI(I)/QR(I))                   OPT19460
      GO TO 555                                                         OPT19470
621   QPSR(I) = -90.                                                    OPT19480
      GO TO 555                                                         OPT19490
622   QPSR(I) = - 57.29577951*DATAN(-QI(I)/QR(I))                       OPT19500
      GO TO 555                                                         OPT19510
623   QPSR(I) = 180.                                                    OPT19520
      GO TO 555                                                         OPT19530
625   QPSR(I) = 0.0                                                     OPT19540
      GO TO 555                                                         OPT19550
626   QPSR(I) = 180.- 57.29577951*DATAN(-QI(I)/QR(I))                   OPT19560
      GO TO 555                                                         OPT19570
627   QPSR(I) = 90.                                                     OPT19580
      GO TO 555                                                         OPT19590
628   QPSR(I) =  57.29577951*DATAN(QI(I)/QR(I))                         OPT19600
      GO TO 555                                                         OPT19610
555   IF(IPHS.EQ.1) GO TO 640                                           OPT19620
      IF((QPSR(I-1).GT.90.).AND.(QPSR(I).LT.-90.)) GO TO 630            OPT19630
      IF((QPSR(I-1).LT.-90.).AND.(QPSR(I).GT.90.)) IPHS = 1             OPT19640
      GO TO 640                                                         OPT19650
630   N = I - 1                                                         OPT19660
      DO 650 L = 1, N                                                   OPT19670
      QPSR(L) = QPSR(L) - 360.                                          OPT19680
```

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650   CONTINUE                                                          OPT19690
640   IF(IPHS.EQ.0) GO TO 700                                           OPT19700
      QPSR(I) = GPSR(I) - 360.                                          OPT19710
700   CONTINUE                                                          OPT19720
80    CONTINUE                                                          OPT19730
      RETURN                                                            OPT19740
751   WRITE(6,752)                                                      OPT19750
      RETURN                                                            OPT19760
C-----------------------------------------------------------------------OPT19770
752   FORMAT (/,5X,'****** PROGRAM FAILURE COMPUTING FREQUENCY ******') OPT19780
C-----------------------------------------------------------------------OPT19790
      END                                                               OPT19800
C=======================================================================OPT19810
C=======================================================================OPT19820
      SUBROUTINE GSETUP(IPTR,PAGEX,PAGEY)                               OPT19830
C     SUBROUTINE GSETUP INTERACTIVELY ALLOWS THE USER TO SELECT EITHER  OPT19840
C     THE TEK618 OR VERSATEC PLOTTER AND SPECIFY A PAGE SIZE            OPT19850
C=======================================================================OPT19860
      INTEGER IPTR,IANS                                                 OPT19870
      REAL*8 ANSR                                                       OPT19880
      REAL*4 PAGEX,PAGEY                                                OPT19890
C-----------------------------------------PLOTTER SELECTION-----------OPT19900
      WRITE(6,100)                                                      OPT19910
10    WRITE(6,110)                                                      OPT19920
      CALL RDINT(IANS)                                                  OPT19930
      IF(IANS.LT.1.OR.IANS.GT.2) GO TO 20                               OPT19940
      GO TO 30                                                          OPT19950
20    WRITE(6,500)                                                      OPT19960
      GO TO 10                                                          OPT19970
30    CONTINUE                                                          OPT19980
      IPTR = IANS                                                       OPT19990
      IF(IPTR.EQ.1) GO TO 80                                            OPT20000
C-----------------------------------------VRSTEC PAGE SIZE------------OPT20010
      CALL FRTCMS('CLRSCRN ')                                           OPT20020
C-----------------------------------------HEIGHT----------------------OPT20030
      WRITE(6,130)                                                      OPT20040
40    WRITE(6,140)                                                      OPT20050
      CALL RDREAL(ANSR)                                                 OPT20060
      IF(ANSR.LT.0.0.OR.IANS.GT.21.0) GO TO 45                          OPT20070
      GO TO 50                                                          OPT20080
45    WRITE(6,510)                                                      OPT20090
      GO TO 40                                                          OPT20100
50    CONTINUE                                                          OPT20110
      PAGEY = ANSR                                                      OPT20120
C-----------------------------------------WIDTH-----------------------OPT20130
60    WRITE(6,150)                                                      OPT20140
      CALL RDREAL(ANSR)                                                 OPT20150
      IF(ANSR.LT.0.0.OR.IANS.GT.21.0) GO TO 65                          OPT20160
```

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      GO TO 70                                                          OPT20170
65    WRITE(6,510)                                                      OPT20180
      GO TO 60                                                          OPT20190
70    CONTINUE                                                          OPT20200
      PAGEX = ANSR                                                      OPT20210
      RETURN                                                            OPT20220
C-----------------------------------------VRSTEC PAGE SIZE-------------OPT20230
80    CONTINUE                                                          OPT20240
      PAGEX = 11.0                                                      OPT20250
      PAGEY = 8.5                                                       OPT20260
      RETURN                                                            OPT20270
C-----------------------------------------------------------------------OPT20280
100   FORMAT(//,5X,'PLOTTER SELECTION AND PAGE SIZE',/,5X,              OPT20290
     *'(NOTE: PAGE IS 11.0 INCHES BY 8.5 INCHES WITH SELECTION OF TEK618OPT20300
     *)',//)                                                            OPT20310
110   FORMAT(/,10X,'WHICH PLOTTER DO YOU DESIRE:',//,15X,'1. TEK618',/, OPT20320
     *15X,'2. VERSATEC',//,10X,'CHOOSE OPTION 1 OR 2')                  OPT20330
130   FORMAT(//,10X,' PAGE SIZE (MAXIMUM = 21.0 INCHES BY 21.0 INCHES)' OPT20340
     *,/)                                                               OPT20350
140   FORMAT(/,15X,'HEIGHT =',//)                                       OPT20360
150   FORMAT(/,15X,'WIDTH =',//)                                        OPT20370
500   FORMAT(//,5X,'***** ERROR ENTER 1 OR 2 *****',//)                 OPT20380
510   FORMAT(//,5X,'***** ERROR MAXIMUM = 21 INCHES *****',//)          OPT20390
      END                                                               OPT20400
C=======================================================================OPT20410
C=======================================================================OPT20420
      SUBROUTINE GGRAF(XMIN,XMAX,YMIN,YMAX)                             OPT20430
C     SUBROUTINE GGRAF INTERACTIVELY ALLOWS THE USER TO SELECT PLOTTING  OPT20440
C     LIMITS FOR USE WITH DISSPLA GRAPHICS                              OPT20450
C=======================================================================OPT20460
      REAL XMIN,XMAX,YMIN,YMAX,ANSR                                     OPT20470
      DATA IY/'Y'/,IZ/'N'/                                              OPT20480
C-----------------------------------------------------------------------OPT20490
40    CONTINUE                                                          OPT20500
      WRITE(6,100)                                                      OPT20510
      WRITE(6,105)                                                      OPT20520
C-----------------------------------------XMIN-----------------------OPT20530
      WRITE(6,110)                                                      OPT20540
      CALL RDREAL(ANSR)                                                 OPT20550
         XMIN = ANSR                                                    OPT20560
C-----------------------------------------XMAX-----------------------OPT20570
      WRITE(6,120)                                                      OPT20580
      CALL RDREAL(ANSR)                                                 OPT20590
         XMAX = ANSR                                                    OPT20600
C-----------------------------------------YAXIS----------------------OPT20610
      WRITE(6,125)                                                      OPT20620
C-----------------------------------------YMIN-----------------------OPT20630
      WRITE(6,130)                                                      OPT20640
```

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      CALL RDREAL(ANSR)                                                 OPT20650
         YMIN = ANSR                                                    OPT20660
C-----------------------------------------YMAX-----------------------OPT20670
      WRITE(6,140)                                                      OPT20680
      CALL RDREAL(ANSR)                                                 OPT20690
         YMAX = ANSR                                                    OPT20700
C-----------------------------------------CORRECTIONS-----------------OPT20710
      CALL FRTCMS('CLRSCRN ')                                           OPT20720
      WRITE(6,100)                                                      OPT20730
      WRITE(6,105)                                                      OPT20740
      WRITE(6,150) XMIN                                                 OPT20750
      WRITE(6,160) XMAX                                                 OPT20760
      WRITE(6,125)                                                      OPT20770
      WRITE(6,170) YMIN                                                 OPT20780
      WRITE(6,180) YMAX                                                 OPT20790
30    WRITE(6,190)                                                      OPT20800
      CALL RDCHAR(IANS)                                                 OPT20810
      IF((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 10                        OPT20820
      GO TO 20                                                          OPT20830
10    WRITE(6,500)                                                      OPT20840
      GO TO 30                                                          OPT20850
20    CONTINUE                                                          OPT20860
      IF(IANS.EQ.IY) GO TO 40                                           OPT20870
      RETURN                                                            OPT20880
C-------------------------------------------------------------------OPT20890
100   FORMAT(//,5X,'PLOTTING LIMITS FOR GRAPH',/)                       OPT20900
105   FORMAT(10X,'X AXIS (REAL AXIS)',/)                                OPT20910
110   FORMAT(15X,'X MINIMUM = ?',/)                                     OPT20920
120   FORMAT(15X,'X MAXIMUM = ?',/)                                     OPT20930
125   FORMAT(10X,'Y AXIS (IMAGINARY AXIS)',/)                           OPT20940
130   FORMAT(15X,'Y MINIMUM = ?',/)                                     OPT20950
140   FORMAT(15X,'Y MAXIMUM = ?',/)                                     OPT20960
150   FORMAT(15X,'X MINIMUM = ',F8.2,/)                                 OPT20970
160   FORMAT(15X,'X MAXIMUM = ',F8.2,/)                                 OPT20980
170   FORMAT(15X,'Y MINIMUM = ',F8.2,/)                                 OPT20990
180   FORMAT(15X,'Y MAXIMUM = ',F8.2,/)                                 OPT21000
190   FORMAT(/,5X,'DO YOU DESIRE TO MAKE ANY CHANGES ?',/,10X,          OPT21010
     *'TYPE "YES" OR "NO".',//)                                         OPT21020
500   FORMAT(/,5X,'****** WARNING *****',/,5X,'IMPROPER DATA ENTRY   ', OPT21030
     *2X,'ENTER "YES" OR "NO".',/)                                      OPT21040
      END                                                               OPT21050
C===================================================================OPT21060
C===================================================================OPT21070
      SUBROUTINE FGRAF(FMIN,FMAX)                                       OPT21080
C     SUBROUTINE FGRAF INTERACTIVELY ALLOWS THE USER TO SELECT PLOTTING OPT21090
C     LIMITS FOR USE WITH DISSPLA GRAPHICS                              OPT21100
C===================================================================OPT21110
      REAL FMIN,FMAX                                                    OPT21120
```

```
      DATA IY/'Y'/,IZ/'N'/                                                  OPT21130
C-----------------------------------------------------------------------OPT21140
40    CONTINUE                                                            OPT21150
      WRITE(6,100)                                                        OPT21160
      WRITE(6,105)                                                        OPT21170
C-------------------------------------------FMIN----------------------OPT21180
50    WRITE(6,110)                                                        OPT21190
      CALL RDREAL(ANSR)                                                   OPT21200
         FMIN = ANSR                                                      OPT21210
      IF(FMIN.GT.0.0) GO TO 60                                            OPT21220
         WRITE(6,510)                                                     OPT21230
         GO TO 50                                                         OPT21240
C-------------------------------------------FMAX----------------------OPT21250
60    WRITE(6,120)                                                        OPT21260
      CALL RDREAL(ANSR)                                                   OPT21270
         FMAX = ANSR                                                      OPT21280
      IF(FMAX.GT.0.0) GO TO 70                                            OPT21290
         WRITE(6,510)                                                     OPT21300
         GO TO 60                                                         OPT21310
C-------------------------------------------CORRECTIONS----------------OPT21320
70    CALL FRTCMS('CLRSCRN ')                                             OPT21330
      WRITE(6,100)                                                        OPT21340
      WRITE(6,105)                                                        OPT21350
      WRITE(6,150) FMIN                                                   OPT21360
      WRITE(6,160) FMAX                                                   OPT21370
80    WRITE(6,190)                                                        OPT21380
      CALL RDCHAR(IANS)                                                   OPT21390
      IF((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 10                          OPT21400
      GO TO 20                                                            OPT21410
10    WRITE(5,500)                                                        OPT21420
      GO TO 80                                                            OPT21430
20    CONTINUE                                                            OPT21440
      IF(IANS.EQ.IY) GO TO 40                                             OPT21450
      RETURN                                                              OPT21460
C-----------------------------------------------------------------------OPT21470
100   FORMAT(//,5X,'PLOTTING LIMITS FOR GRAPH',/)                         OPT21480
105   FORMAT(10X,'FREQUENCY RANGE - RADIANS PER SECOND',/)                OPT21490
110   FORMAT(15X,'MINIMUM FREQUENCY = ?',/)                               OPT21500
120   FORMAT(15X,'MAXIMUM FREQUENCY = ?',/)                               OPT21510
150   FORMAT(15X,'MINIMUM FREQUENCY = ',E15.3,/)                          OPT21520
160   FORMAT(15X,'MAXIMUM FREQUENCY = ',E15.3,/)                          OPT21530
190   FORMAT(/,5X,'DO YOU DESIRE TO MAKE ANY CHANGES ?',/,10X,            OPT21540
     *'TYPE "YES" OR "NO".',//)                                           OPT21550
500   FORMAT(/,5X,'****** WARNING ******',/,5X,'IMPROPER DATA ENTRY   ',  OPT21560
     *3X,'ENTER "YES" OR "NO".',/)                                        OPT21570
510   FORMAT(/,5X,'****** WARNING ******',/,5X,'IMPROPER DATA ENTRY   ',  OPT21580
     *3X,'FREQUENCY MUST BE GREATER THAN ZERO.',/)                        OPT21590
      END                                                                 OPT21600
```

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C=====================================================================OPT21610
C=====================================================================OPT21620
      SUBROUTINE RANGK(KMIN,KMAX)                                      OPT21630
C     SUBROUTINE RANGK INTERACTIVELY ALLOWS THE USER TO SELECT GAIN    OPT21640
C     LIMITS FOR USE WITH ROOT-LOCUS PLOTS                             OPT21650
C=====================================================================OPT21660
      REAL*8 KMIN,KMAX                                                 OPT21670
      DATA IY/'Y'/,IZ/'N'/                                             OPT21680
C---------------------------------------------------------------------OPT21690
40    CONTINUE                                                         OPT21700
      WRITE(6,100)                                                     OPT21710
C-----------------------------------------KMIN------------------------OPT21720
50    WRITE(6,110)                                                     OPT21730
      CALL RDREAL(ANSR)                                                OPT21740
         KMIN = ANSR                                                   OPT21750
C-----------------------------------------KMAX------------------------OPT21760
60    WRITE(6,120)                                                     OPT21770
      CALL RDREAL(ANSR)                                                OPT21780
         KMAX = ANSR                                                   OPT21790
C---------------------------------------CORRECTIONS--------------------OPT21800
70    CALL FRTCMS('CLRSCRN ')                                          OPT21810
      WRITE(6,100)                                                     OPT21820
      WRITE(6,150) KMIN                                                OPT21830
      WRITE(6,160) KMAX                                                OPT21840
80    WRITE(6,190)                                                     OPT21850
      CALL RDCHAR(IANS)                                                OPT21860
      IF((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 10                       OPT21870
      GO TO 20                                                         OPT21880
10    WRITE(5,500)                                                     OPT21890
      GO TO 30                                                         OPT21900
20    CONTINUE                                                         OPT21910
      IF(IANS.EQ.IY) GO TO 40                                          OPT21920
      RETURN                                                           OPT21930
C---------------------------------------------------------------------OPT21940
100   FORMAT(//,5X,'GAIN RANGE FOR ROOT-LOCUS PLOT',//)                OPT21950
110   FORMAT(15X,'MINIMUM GAIN = ?',/)                                 OPT21960
120   FORMAT(15X,'MAXIMUM GAIN = ?',/)                                 OPT21970
150   FORMAT(15X,'MINIMUM GAIN = ',E15.3,/)                            OPT21980
160   FORMAT(15X,'MAXIMUM GAIN = ',E15.3,/)                            OPT21990
190   FORMAT(/,5X,'DO YOU DESIRE TO MAKE ANY CHANGES ?',/,10X,         OPT22000
     *'TYPE "YES" OR "NO".',//)                                        OPT22010
500   FORMAT(/,5X,'****** WARNING ******',/,5X,'IMPROPER DATA ENTRY   ',OPT22020
     *3X,'ENTER "YES" OR "NO".',/)                                     OPT22030
      END                                                              OPT22040
C=====================================================================OPT22050
C=====================================================================OPT22060
      SUBROUTINE CHEAD(NL)                                             OPT22070
C     SUBROUTINE CHEAD INTERACTIVELY ALLOWS THE USER TO INPUT THREE    OPT22080
```

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C     LINES OF HEADING FOR USE WITH DISSPLA GRAPHICS                    OPT22090
C=======================================================================OPT22100
      INTEGER NL,LINES,I,IANS,LINE                                      OPT22110
      COMMON /SHEAD/ LINES(4,18),LINE(9)                                OPT22120
      DATA IY/'Y'/,IZ/'N'/                                              OPT22130
C-----------------------------------------------------------------------OPT22140
      WRITE(6,10C)                                                      OPT22150
10    WRITE(6,11C)                                                      OPT22160
      CALL RDINT(IANS)                                                  OPT22170
      IF(IANS.GT.3) GO TO 30                                            OPT22180
      GO TO 20                                                          OPT22190
30    WRITE(6,51C)                                                      OPT22200
      GO TO 10                                                          OPT22210
20    CONTINUE                                                          OPT22220
      IF(IANS.LT.C) GO TC 35                                            OPT22230
      GO TO 25                                                          OPT22240
35    WRITE(6,520)                                                      OPT22250
      GO TO 10                                                          OPT22260
25    CONTINUE                                                          OPT22270
      NL = IANS                                                         OPT22280
      IF(NL.EQ.0) GO TO 70                                              OPT22290
      WRITE(6,120)                                                      OPT22300
      DO 50 I = 1,NL                                                    OPT22310
         WRITE(6,130) I                                                 OPT22320
         CALL RLINE(I)                                                  OPT22330
50    CONTINUE                                                          OPT22340
C-----------------------------------------CORRECTICNS-----------------OPT22350
8C    CALL FRTCMS('CLRSCRN ')                                           OPT22360
      WRITE(6,100)                                                      OPT22370
      DO 60 I = 1,NL                                                    OPT22380
         WRITE(6,140) I,(LINES(I,J),J=1,9)                              OPT22390
60    CONTINUE                                                          OPT22400
63    WRITE(6,150)                                                      OPT22410
      CALL RDCHAR(IANS)                                                 OPT22420
      IF((IANS.NE.IY).AND.(IANS.NE.IZ)) GO TO 61                        OPT22430
      GO TO 62                                                          OPT22440
61    WRITE(6,500)                                                      OPT22450
      GO TO 63                                                          OPT22460
62    CONTINUE                                                          OPT22470
      IF(IANS.EQ.IZ) GO TC 70                                           OPT22480
77    WRITE(6,160)                                                      OPT22490
      CALL RDINT(IANS)                                                  OPT22500
         IF((IANS.LT.1).OR.(IANS.GT.NL)) GO TO 75                       OPT22510
         GO TO 76                                                       OPT22520
75    CONTINUE                                                          OPT22530
         WRITE(6,530)                                                   OPT22540
         GO TO 77                                                       OPT22550
76    CONTINUE                                                          OPT22560
```

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         WRITE(6,130) IANS                                                      OPT22570
         CALL RLINE(IANS)                                                       OPT22580
         GO TO 80                                                               OPT22590
70    CONTINUE                                                                  OPT22600
      RETURN                                                                    OPT22610
C-----------------------------------------------------------------------       OPT22620
100   FORMAT(//,5X,'PLOT HEADING',/)                                            OPT22630
110   FORMAT(/,10X,'HOW MANY LINES OF HEADING DO YOU DESIRE ? ( 3 MAX )'        OPT22640
     *,/,15X,'ENTER NUMBER OF LINES.  ( ENTER "0" FOR NO HEADING )',/)          OPT22650
120   FORMAT(/,10X,'A MAXIMUM OF 32 CHARACTERS PER LINE IS ALLOWED',/)          OPT22660
130   FORMAT(/,10X,'LINE',I2,' IS:',/)                                          OPT22670
140   FORMAT(/,10X,'LINE',I2,' :',5X,9A4,/)                                     OPT22680
150   FORMAT(/,5X,'DO YOU DESIRE TO MAKE ANY CHANGES ?',/,10X,                  OPT22690
     *'TYPE "YES" OR "NO".',//)                                                 OPT22700
160   FORMAT(/,5X,'ENTER LINE NUMBER TO BE CHANGED.',/)                         OPT22710
500   FORMAT(/,5X,'****** WARNING *****',/,5X,'IMPROPER DATA ENTRY   ',         OPT22720
     *3X,'ENTER "YES" OR "NO".',/)                                              OPT22730
510   FORMAT(/,5X,'****** ERROR: 3 LINES MAXIMUM ******',/)                     OPT22740
520   FORMAT(/,5X,'****** ERROR: 0 LINES MINIMUM ******',/)                     OPT22750
530   FORMAT(/,5X,'****** WARNING *****',5X,'IMPROPER DATA ENTRY   ',/)         OPT22760
      END                                                                       OPT22770
C=======================================================================       OPT22780
C=======================================================================       OPT22790
      SUBROUTINE RLINE(ILN)                                                     OPT22800
C  SUBROUTINE TO READ IN A STRING OF CHARACTERS OR LINE.  IF THE USER          OPT22810
C  INADVERTENTLY ENTERS A NULL STRING, THE S/R ISSUES A WARNING AND           OPT22820
C  ALLOWS A RECOVERY.  TWO NULL STRINGS & YOU ARE OUT                         OPT22830
C=======================================================================       OPT22840
      INTEGER ILN,LINES,BLANK,COUNT,I,LINE                                      OPT22850
      COMMON /SHEAD/ LINES(4,18),LINE(9)                                        OPT22860
C-----------------------------------------------------------------------       OPT22870
      DATA BLANK/'    '/                                                        OPT22880
      DO 5 I=1,18                                                               OPT22890
         LINES(ILN,I)=BLANK                                                     OPT22900
5     CONTINUE                                                                  OPT22910
      COUNT=0                                                                   OPT22920
10    COUNT=COUNT+1                                                             OPT22930
      IF(COUNT.LT.3) GO TO 20                                                   OPT22940
         WRITE(6,60)                                                            OPT22950
      GO TO 40                                                                  OPT22960
20    CONTINUE                                                                  OPT22970
      REWIND 4                                                                  OPT22980
      READ(5,70,END=30,ERR=30)(LINES(ILN,J),J=1,9)                              OPT22990
      RETURN                                                                    OPT23000
30    REWIND 4                                                                  OPT23010
      WRITE(6,50)                                                               OPT23020
      GO TO 10                                                                  OPT23030
40    CONTINUE                                                                  OPT23040
```

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      STOP                                                                  OPT23050
C-----------------------------------------------------------------------    OPT23060
50    FORMAT(1X,'WARNING: NULL STRINGS ARE NOT ALLOWED, ENTER',             OPT23070
     *1X,'CHARACTER VALUES.')                                               OPT23080
60    FORMAT(////,2X,42HPROGRAM KILLED - TWO NULL STRINGS ENTERED ,/)       OPT23090
70    FORMAT(9A4)                                                           OPT23100
      END                                                                   OPT23110
C=======================================================================    OPT23120
C=======================================================================    OPT23130
      SUBROUTINE CLINE(ILN)                                                 OPT23140
C  SUBROUTINE PLACES A DOLLAR SIGN AT THE END OF A CHARACTER STING          OPT23150
C  ENTERED FROM THE KEYBOARD AND PLACES THE RESULTING STRING INTO           OPT23160
C  A 1-D ARRAY TO BE USED BY DISSPLA                                        OPT23170
C=======================================================================    OPT23180
      INTEGER I,ILN,LINES,J,LINE,DOLLAR,BLANK                               OPT23190
      COMMON /SHEAD/ LINES(4,18),LINE(9)                                    OPT23200
C-----------------------------------------------------------------------    OPT23210
      DATA DOLLAR/'$   '/,BLANK/'    '/                                     OPT23220
      DO 10 I=1,9                                                           OPT23230
         J=I                                                                OPT23240
         LINE(I)=LINES(ILN,I)                                               OPT23250
         IF(LINE(I).EQ.BLANK) GO TO 20                                      OPT23260
10    CONTINUE                                                              OPT23270
20    LINE(J)=DOLLAR                                                        OPT23280
      RETURN                                                                OPT23290
      END                                                                   OPT23300
C=======================================================================OPT23310
C=======================================================================OPT23320
C  SUBROUTINE RDREAL -- INTERACTIVELY READS A REAL NUMBER REPLY          =OPT23330
C  INTO A FORTRAN PROGRAM.  IF THE USER INADVERTENLY ENTERS  A NULL      =OPT23340
C  STRING THE S/R ISSUES A WARNING AND ALLOWS A RECOVERY.                =OPT23350
C=======================================================================OPT23360
      SUBROUTINE RDREAL (ANSR)                                              OPT23370
      REAL*8 ANSR                                                           OPT23380
      INTEGER COUNT                                                         OPT23390
C-----------------------------------------------------------------------OPT23400
      COUNT=0                                                               OPT23410
10    CONTINUE                                                              OPT23420
      COUNT=COUNT+1                                                         OPT23430
      IF (COUNT.LT.3) GO TO 20                                              OPT23440
      WRITE (6,60)                                                          OPT23450
      GO TO 40                                                              OPT23460
20    CONTINUE                                                              OPT23470
      READ (5,*,END=30,ERR=30) ANSR                                         OPT23480
      RETURN                                                                OPT23490
30    REWIND 5                                                              OPT23500
      WRITE (6,50)                                                          OPT23510
      GO TO 10                                                              OPT23520
```

```
40    CONTINUE                                                          OPT23530
      STOP                                                              OPT23540
C-----------------------------------------------------------------------OPT23550
50    FORMAT (1X,64HWARNING:  NULL STRINGS ARE NOT ALLOWED, ENTER A NUMEOPT23560
     1RICAL VALUE.)                                                     OPT23570
60    FORMAT (////,2X,42HPROGRAM KILLED - TWO NULL STRINGS ENTERED ,/)  OPT23580
      END                                                               OPT23590
C=======================================================================OPT23600
C=======================================================================OPT23610
C  SUBROUTINE RDINT -- INTERACTIVELY READS AN INTEGER REPLY             =OPT23620
C  INTO A FORTRAN PROGRAM.  IF THE USER INADVERTENLY ENTERS  A NULL     =OPT23630
C  STRING THE S/R ISSUES A WARNING AND ALLOWS A RECOVERY.               =OPT23640
C=======================================================================OPT23650
      SUBROUTINE RDINT (IANS)                                           OPT23660
      INTEGER COUNT,IANS                                                OPT23670
C-----------------------------------------------------------------------OPT23680
      COUNT=0                                                           OPT23690
10    CONTINUE                                                          OPT23700
      COUNT=COUNT+1                                                     OPT23710
      IF (COUNT.LT.3) GO TO 20                                          OPT23720
      WRITE (6,60)                                                      OPT23730
      GO TO 40                                                          OPT23740
20    CONTINUE                                                          OPT23750
      READ (5,*,END=30,ERR=30) IANS                                     OPT23760
      RETURN                                                            OPT23770
30    REWIND 5                                                          OPT23780
      WRITE (6,50)                                                      OPT23790
      GO TO 10                                                          OPT23800
40    CONTINUE                                                          OPT23810
      STOP                                                              OPT23820
C-----------------------------------------------------------------------OPT23830
50    FORMAT (1X,64HWARNING:  NULL STRINGS ARE NOT ALLOWED, ENTER A NUMEOPT23840
     1RICAL VALUE.)                                                     OPT23850
60    FORMAT (////,2X,42HPROGRAM KILLED - TWO NULL STRINGS ENTERED ,/)  OPT23860
      END                                                               OPT23870
C=======================================================================OPT23880
C=======================================================================OPT23890
C  SUBROUTINE RDCHAR -- INTERACTIVELY READS A CHARACTER STRING REPLY    =OPT23900
C  ('YES' OR 'NO') INTO A FORTRAN PROGRAM.  IF THE USER INADVERTENLY    =OPT23910
C  ENTERS  A NULL STRING THE S/R ISSUES A WARNING AND ALLOWS A RECOVERY=OPT23920
C=======================================================================OPT23930
      SUBROUTINE RDCHAR (IANS)                                          OPT23940
      INTEGER COUNT,IANS                                                OPT23950
C-----------------------------------------------------------------------OPT23960
      COUNT=0                                                           OPT23970
10    CONTINUE                                                          OPT23980
      COUNT=COUNT+1                                                     OPT23990
      IF (COUNT.LT.3) GO TO 20                                          OPT24000
```

```
      WRITE (6,6C)                                                      OPT24010
      GO TO 40                                                          OPT24020
2C    CONTINUE                                                          OPT24030
      REWIND 5                                                          OPT24040
      READ (5,70,END=30,ERR=30) IANS                                    OPT24050
      RETURN                                                            OPT24060
3C    REWIND 5                                                          OPT24070
      WRITE (6,5C)                                                      OPT24080
      GO TO 10                                                          OPT24090
4C    CONTINUE                                                          OPT24100
      STOP                                                              OPT24110
C-----------------------------------------------------------------------OPT24120
5C    FORMAT (1X,6OHWARNING:  NULL STRINGS ARE NOT ALLOWED, ENTER "YES" OPT24130
     1OR "NO".)                                                         OPT24140
6C    FORMAT (////,2X,42HPROGRAM KILLED - TWO NULL STRINGS ENTERED ,/)  OPT24150
7C    FORMAT (A1)                                                       OPT24160
      END                                                               OPT24170
C=======================================================================OPT24180
C=======================================================================OPT24190
      SUBROUTINE MINMAX(N,AA,MIN,MAX)                                   OPT24200
C     SUBROUTINE MINMAX FINDS THE MINIMUM AND MAXIMUM VALUES FOR A ONE  OPT24210
C     DIMENSIONAL ARRAY                                                 OPT24220
C=======================================================================OPT24230
      REAL*4 MIN,MAX,AA                                                 OPT24240
      INTEGER N                                                         OPT24250
      DIMENSION AA(N)                                                   OPT24260
C-----------------------------------------------------------------------OPT24270
      MAX = AA(1)                                                       OPT24280
      MIN = AA(1)                                                       OPT24290
      DO 10 I = 1,N                                                     OPT24300
      IF(AA(I).GT.MAX) GO TO 5                                          OPT24310
      IF(AA(I).LT.MIN) GO TO 6                                          OPT24320
      GO TO 10                                                          OPT24330
5     MAX = AA(I)                                                       OPT24340
      GO TO 10                                                          OPT24350
6     MIN = AA(I)                                                       OPT24360
10    CONTINUE                                                          OPT24370
      RETURN                                                            OPT24380
      END                                                               OPT24390
C=======================================================================OPT24400
C=======================================================================OPT24410
      SUBROUTINE MAKPOL(N,R,C)                                          OPT24420
C     SUBROUTINE MAKPOL COMPUTES THE COMPLEX COEFFICIENTS OF AN N-TH    OPT24430
C     DEGREE POLYNOMIAL GIVEN N COMPLEX ROOTS OF THE POLYNOMIAL         OPT24440
C=======================================================================OPT24450
      COMPLEX*16 R(N),C(N)                                              OPT24460
      IF(N.LE.0) RETURN                                                 OPT24470
      DO 10 I=1,N                                                       OPT24480
```

```
   10 C(I)=R(I)                                                          OPT24490
      IF(N.NE.1)GO TO 15                                                 OPT24500
      I=1                                                                OPT24510
      GO TO 40                                                           OPT24520
   15 K=N                                                                OPT24530
      M=N-1                                                              OPT24540
      DO 20 L=1,M                                                        OPT24550
      DO 30 I=2,K                                                        OPT24560
   30 C(I)=C(I)+C(I-1)                                                   OPT24570
      K=K-1                                                              OPT24580
      DO 20 I=1,K                                                        OPT24590
      J=I+L                                                              OPT24600
      C(I)=R(J)*C(I)                                                     OPT24610
   20 CONTINUE                                                           OPT24620
      K=N/2                                                              OPT24630
      K=2*K/(N-K)                                                        OPT24640
      DO 40 I=K,N,2                                                      OPT24650
   40 C(I)=-C(I)                                                         OPT24660
      RETURN                                                             OPT24670
C-----------------------------------------------------------------------OPT24680
      END                                                                OPT24690
C=======================================================================OPT24700
C=======================================================================OPT24710
      SUBROUTINE PRTPLT(IPP)                                             OPT24720
C     SUBROUTINE PRTPLT INTERACTIVELY ALLOWS THE USER TO SELECT EITHER   OPT24730
C     GRAPHICAL OUTPUT, TABULAR DATA, OR TO QUIT.                        OPT24740
C=======================================================================OPT24750
      INTEGER IPTR,IANS                                                  OPT24760
C-----------------------------------------------------------------------OPT24770
      WRITE(6,100)                                                       OPT24780
   30 WRITE(6,110)                                                       OPT24790
      CALL RDINT(IANS)                                                   OPT24800
      IF(IANS.GT.3.OR.IANS.LT.1) GO TO 15                                OPT24810
      GO TO 25                                                           OPT24820
   15 WRITE(6,510)                                                       OPT24830
      GO TO 30                                                           OPT24840
   25 CONTINUE                                                           OPT24850
      IPP = IANS                                                         OPT24860
C-----------------------------------------------------------------------OPT24870
      RETURN                                                             OPT24880
C-----------------------------------------------------------------------OPT24890
  100 FORMAT(//,5X,'DO YOU DESIRE:',//,                                  OPT24900
     *10X,'1.  GRAPHICAL OUTPUT',/,                                      OPT24910
     *10X,'2.  TABULAR DATA',/,                                          OPT24920
     *10X,'3.  QUIT SUBROUTINE',/)                                       OPT24930
  110 FORMAT(/,5X,'ENTER OPTION NUMBER.',/)                              OPT24940
  510 FORMAT(/,5X,'****** ERROR ******',10X,'IMPROPER DATA ENTRY',/)     OPT24950
C-----------------------------------------------------------------------OPT24960
```

```
      END                                                                OPT24970
C=====================================================================OPT24980
C=====================================================================OPT24990
      SUBROUTINE PRTR(IPT)                                               OPT25000
C     SUBROUTINE PRTR INTERACTIVELY ALLOWS THE USER TO SELECT THE        OPT25010
C     THE OUTPUT DEVICE FOR TABULAR DATA.                                OPT25020
C=====================================================================OPT25030
      INTEGER IPT,IANS                                                   OPT25040
C---------------------------------------------------------------------OPT25050
      WRITE(6,100)                                                       OPT25060
30    WRITE(6,110)                                                       OPT25070
      CALL RDINT(IANS)                                                   OPT25080
      IF(IANS.GT.3.OR.IANS.LT.1) GO TO 15                                OPT25090
      GO TO 25                                                           OPT25100
15    WRITE(6,510)                                                       OPT25110
      GO TO 30                                                           OPT25120
25    CONTINUE                                                           OPT25130
      GO TO (40,50,60),IANS                                              OPT25140
40    IPT = 6                                                            OPT25150
      GO TO 80                                                           OPT25160
50    IPT = 3                                                            OPT25170
      GO TO 80                                                           OPT25180
60    IPT = 2                                                            OPT25190
      GO TO 80                                                           OPT25200
C---------------------------------------------------------------------OPT25210
80    RETURN                                                             OPT25220
C---------------------------------------------------------------------OPT25230
100   FORMAT(//,5X,'DO YOU DESIRE TABULAR OUTPUT TO GO TO:',//,          OPT25240
     *10X,'1.  SCREEN',/,                                               OPT25250
     *10X,'2.  PRINTER',/,                                              OPT25260
     *10X,'3.  DISK (OPGRAPH LISTING)',/)                               OPT25270
110   FORMAT(/,5X,'ENTER OPTION NUMBER.',/)                              OPT25280
510   FORMAT(/,5X,'****** ERROR ******',10X,'IMPROPER DATA ENTRY',/)     OPT25290
C---------------------------------------------------------------------OPT25300
      END                                                                OPT25310
C=====================================================================OPT25320
C=====================================================================OPT25330
      SUBROUTINE NPTS(PTS)                                               OPT25340
C     SUBROUTINE NPTS INTERACTIVELY ALLOWS THE USER TO SELECT THE NUMBEROPT25350
C     OF POINTS TO BE CALCULATED FOR TABULAR DATA                        OPT25360
C=====================================================================OPT25370
      INTEGER PTS,IANS                                                   OPT25380
C---------------------------------------------------------------------OPT25390
      WRITE(6,100)                                                       OPT25400
30    WRITE(6,110)                                                       OPT25410
      CALL RDINT(IANS)                                                   OPT25420
      IF(IANS.GT.500.OR.IANS.LT.1) GO TO 15                              OPT25430
      GO TO 25                                                           OPT25440
```

```
15    WRITE(6,510)                                                          OPT25450
      GO TO 30                                                              OPT25460
25    CONTINUE                                                              OPT25470
      PTS = IANS                                                            OPT25480
C-----------------------------------------------------------------------OPT25490
      RETURN                                                                OPT25500
C-----------------------------------------------------------------------OPT25510
100   FORMAT(//,5X,'HOW MANY POINTS DO YOU WANT TO TABULATE?',/,            OPT25520
     *10X,'(500 IS THE MAXIMUM)',/)                                         OPT25530
110   FORMAT(/,5X,'ENTER NUMBER OF POINTS.',/)                              OPT25540
510   FORMAT(/,5X,'****** ERROR ******',10X,'MUST ENTER BETWEEN 1 AND 500PT25550
     *0 POINTS  ',/)                                                        OPT25560
C-----------------------------------------------------------------------OPT25570
      END                                                                   OPT25580
C=======================================================================OPT25590
C=======================================================================OPT25600
      SUBROUTINE PSCALE(PAGEX)                                              OPT25610
C     SUBROUTINE PSCALE AUTOMATICALLY SCALES DISSPLA PLOTS                  OPT25620
C=======================================================================OPT25630
      REAL*4 PAGEX,TS,TH,TH1,T1,T2,T3,T4,T5,T6,T7,T8,T9,T10                 OPT25640
      COMMON /SCALE/ TS,TH,TH1,T1,T2,T3,T4,T5,T6,T7,T8,T9,T10               OPT25650
C-----------------------------------------------------------------------OPT25660
      TS = PAGEX/11.0                                                       OPT25670
      TH = 0.14*TS                                                          OPT25680
      TH1 = 0.10*TS                                                         OPT25690
      T1 = 0.60*TS                                                          OPT25700
      T2 = 1.60*TS                                                          OPT25710
      T3 = 1.20                                                             OPT25720
      T4 = 0.30*TS                                                          OPT25730
      T5 = 2.10*TS                                                          OPT25740
      T6 = 0.9 *TS                                                          OPT25750
      T7 = 2.00*TS                                                          OPT25760
      T8 = 0.20*TS                                                          OPT25770
      T9 = 2.0*TS                                                           OPT25780
      T10 = 3.0*TS                                                          OPT25790
      IF(PAGEX.LT.6.0) T3 =1.0                                              OPT25800
      RETURN                                                                OPT25810
C-----------------------------------------------------------------------OPT25820
      END                                                                   OPT25830
```

APPENDIX D
OPGRAPH LISTING

This portion of the thesis contains a sample of tabular output sent to a disk (OPGRAPH LISTING)

BODE PLOT
COMPENSATOR TRANSFER FUNCTION

INPUT NUMBER = 1
OUTPUT NUMBER = 1
DENOMINATOR ORDER = 2
NUMERATOR ORDER = 1
TRANSFER FUNCTION (DC) GAIN = -0.1135D+06

FREQUENCY (RAD/SEC)	MAGNITUDE (DECIBELS)	PHASE (DEGREES)	REAL PART	IMAGINARY PART
0.1000D+02	0.4815D+02	-0.1482D+03	-0.2171D+03	-0.1346D+03
0.1778D+02	0.5106D+02	-0.1401D+03	-0.2740D+03	-0.2292D+03
0.3162D+02	0.5504D+02	-0.1423D+03	-0.4466D+03	-0.3456D+03
0.5623D+02	0.5891D+02	-0.1629D+03	-0.8431D+03	-0.2598D+03
0.1000D+03	0.5956D+02	-0.2025D+03	-0.8786D+03	0.3637D+03

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210349

Thesis
L2673 Laptas
c.1 Development of graphical Pole-Zero, Root-Locus, Bode, Nyquist, and Nichols responses using the OPTSYSX Program.